MILITARY SYSTEMS DESIGN

MAY-JUNE 1960

featuring:

Infrared Techniques
Microcircuit Techniques
Electronic Circuitry

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MSD MILITARY SYSTEMS DESIGN

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VOLUME 4, NUMBER 3
MAY-JUNE 1960

COVER: Advanced microcircuitry techniques are typified by a Solid Circuit semiconductor network unit (see page 5) posed against its circuit diagram on which conventional miniature components are mounted. Courtesy of Texas Instruments Incorporated.

MSD editorial

IR and Microcircuits Linked to "Spy" Satellites

Events of the past few weeks have raised to levels of international importance the topics selected for special emphasis in this issue. The MIDAS II Air Force satellite, launched within days after the collapse of the Summit Meeting in Paris, served notice that the art of large-scale military surveillance has been freed from dependence on manned aircraft. MIDAS, equipped with infrared scanners, will demonstrate that a fleet of such satellites could continuously survey the entire surface of the globe to identify and warn of any missile firings. A major feature on Background Limited Infrared Detectors, by Dr. I. H. Swift discusses design considerations typical of this technique.

In hearings before the Senate Committee on Appropriations, the NASA has requested a restoration of fiscal year 1961 budget cuts amounting to about $39 million, from a total of $915 million originally requested. Dr. Hugh L. Dryden and others pointed out that missiles now being successfully launched were produced under 1959 and 1960 budgets, and that as missiles increase in their weight-lifting capabilities, their cost, complexity and lead-times become correspondingly longer. Consequently 1961 appropriations will determine our international posture in space, not only next year, but in 1963 or even later. He also warned that for the next several years the U. S. space program now planned will require annual support upwards of $1½ billion.

Space programs, above all others, require electronic systems designed for high component density and the highest possible reliability. Satellite-borne systems, within the foreseeable future, must operate without maintenance. These considerations add urgency to our second topic of emphasis: Ultra-miniature solid state circuits, or microcircuitry.

A wide variety of opinions exist on the *immediate* practicality of ultra-miniature circuits for the majority of Military Systems. We have tried to provide editorial space for proponents of various viewpoints and philosphies concerning this rapidly developing discipline. Nor do we terminate the discussion in this issue. MILITARY SYSTEMS DESIGN will provide additional articles in succeeding issues on late microcircuit developments which could not be cleared in time for this deadline.

Inexorably, technical progress is forcing the world powers into new positions of co-existence which call for different international agreements than now exist. The Russians are not the only nation reluctant to entrust any part of their national security to a central world authority. Contrary to

the usual impression gained from news reports, most of the proposals advanced by U.S. negotiators in the East-West talks, if accepted by the Russians, would require Senate authorization or major revision of present U. S. laws. Americans must also be prepared to make important concessions to implement any international plan of inspection.

The President's plan, promoting United Nation's control of international inspections by aircraft or by robot satellites, could lead to coordination in other aspects of mutual security, and develop into a reliable political mechanism for keeping the peace. Besides easing world tensions, such international cooperation might allow for a more orderly development of space systems, and give time for basic research to make some sorely-needed breakthroughs.

Although the NASA is designated the "non-military" space agency, every advance made in operational space capabilities has military implications. Very soon the ability to neutralize or destroy enemy vehicles in space may become urgent. Progress in the "state of the art" of microcircuitry and IR detection as applied in Military Systems may even be more vital than we suspect.

Semiconservative View of the Semiconductor Future

Dr. Harper Q. North, President of Pacific Semiconductors, Inc., in the keynote speech before the 7th Regional Technical Program of the IRE forecast the following trends in the future of semiconductors:

That ultimately 80% to 90% of all germanium semiconductor devices will be replaced by silicon type devices when technologies for the production of silicon devices become equally advanced.

That intermetallic compounds such as gallium arsenide will be increasingly used where high temperature and high frequency performance are important limiting factors, and where high chemical purity and crystal perfection are not vital.

That increased use will be made of varactor diodes, but that tunnel diodes may be limited to the field of UHF oscillators and amplifiers unless a third control electrode can be added to make them more adaptable to switching circuits.

The transistors may have reached a limit in frequency at about 2500 mc but that higher powers of around 5 Kw in the 5 to 10 mc range may eventually be possible.

That when their cost is reduced, the uses of controlled rectifiers will be extended to applications where expensive variable inductances or thyratrons could not be justified.

That although solid state circuits—each comprising an assembly of diodes, transistors, resistors, and voltage variable capacitors, all formed within a single block of semiconductor material—will one day be in widespread use; the present stage of semiconductor technology prevents a high yield in production.

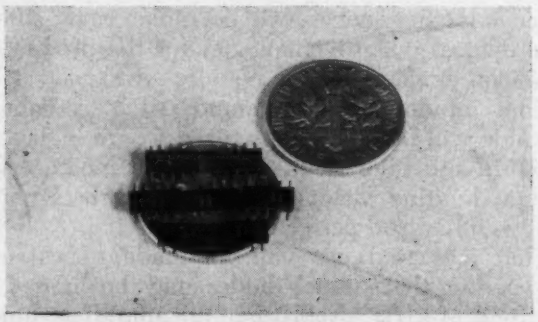
Dr. North added, "Reliability has been touted as

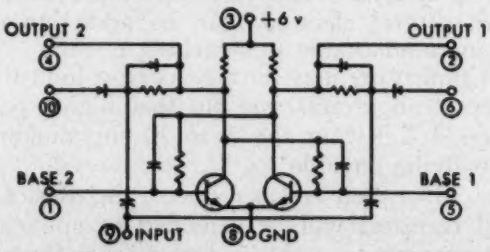
(*Continued on page* 51)

THE NEED FOR MIC

MICROMINIATURE or functional devices of many different designations are currently being offered by the nation's leading designers. These include ceramic-base printed circuits, microcircuits, micrologic elements, micro-modules, molecular electronics, thin films, and semiconductor networks. To date, the industry is not yet agreed on the problems they are trying to solve for the military. Reliability, miniaturization (reduced size and weight), standardization, maintainability and more economically priced equipment, are among the most frequently mentioned objectives.

Clearly, many of the current approaches to microminiaturization mentioned above achieve miniaturization to a degree than is considered necessary for many military applications today. The trend toward microminiaturization, however, is expected to continue indefinitely. Consequently, those approaches which offer greatest advantages from this view point stand to gain favor with time. TI believes that Solid Circuit ® semiconductor networks offer as great a degree of miniaturization as any approach yet known.





SOLID CIRCUIT semiconductor networks, here shown seven on a dime, are typical of one class of microcircuits now available to design engineers. These new units perform as multivibrator, phase-shift oscillator, logic circuits counters, gates and other functional entities which are equivalent to conventional circuits in which resistors, capacitors, transistors and diodes are separate components.

®Solid Circuit is a trademark of Texas Instruments Incorporated, and is used with the generic term semiconductor networks.

MICROMINIATURIZATION

HARRY L. OWENS,
Texas Instruments Inc.

Mr. Harry L. Owens is head of all silicon transistor, semiconductor networks, and materials and sensors operations at the Semiconductor-Components Division, Texas Instruments Incorporated, Dallas, Texas.

Additionally, the contribution of solid circuit networks to military electronic equipment will be of even greater value because of the improved system reliability which we expect to make possible. Within a year, the validity of this feature will be demonstrated. Faith in the potentially higher reliability of solid circuit semiconductor networks is based on the obvious advantage of dramatically reducing the number of physical connections which will be required to produce an item of electronic hardware. Furthermore, the solid circuit semiconductor network approach has an additional advantage in that the network consists of a continuum of like materials, avoiding the potential reliability problems inherent in the assembly of a group of dissimilar solids.

Unlike some other microminiaturization approaches, with Solid Circuit semiconductor networks it is not necessary to compromise engineering standards to affect dramatic size reductions. For example, a diode or a transistor element in a Solid Circuit semiconductor network has the identical dimensions of its presently produced commercial counter-part. Techniques developed in the valuable past experience of TI engineers have permitted them to combine these elements in a unique manner, producing the entire circuit function within a single piece of semiconductor material. The state of this new art is now capable of executing for specific design engineering Solid Circuit semiconductor networks in large volume military and commercial applications.

One of the distinguishing characteristics of Texas Instruments' semi-conductor networks design is that the conductance paths in the semiconductor are related to the classical circuit elements of resistance, capacitance, transistors, and diodes. In this manner, a wide variety of semiconductor networks may be designed in an orderly and predictable fashion. This allows Texas Instruments to truly tailor their design of each device to the over-all system requirement of the customer.

This approach is used as the basis or point of departure for each new design. However, the design of each device is not necessarily a one-for-one relationship between the conductance paths and the circuit elements. Multiple effects within the semiconductor may have to be considered, as well as the inclusion of other semiconductor effects such as PNPN, field-effect, and tunnel-effects, in order to achieve the desired performance.

One of the important aspects of the semiconductor network program is Texas Instruments firm belief that this product can best serve the electronic market by making available what is known and can be manufactured today. Thereafter, the inclusion of more complex semiconductor devices may be an evolutionary process. We expect a greater contribution will be made to the electronic industry by advancing the technology of new semiconductor devices as a separate program apart from semiconductor networks. As these technologies are understood, they may then be applied to semiconductor networks. Some of the confusion existing today among the many miniaturization programs is due to attempts to merge these efforts into one program.

These devices are made principally by selective diffusion and shaping of the semiconductor material, after it is in the single crystalline state. Selective diffusion may be accomplished by using one of several masking materials, i.e., silicon dioxide for silicon. These masking materials will allow certain diffusants to penetrate into the semiconductor in only the unmasked areas. Selective shaping may be obtained by the use of acid resistant masks. Both of these masks, diffusion and shaping, are defined by photolithographic techniques. These consist of exposing a photoemulsion through a pattern in a photographic film. The exposed area of the emulsion is washed away during the developing, exposing the subsurface in the desired pattern for subsequent working.

For the immediate evaluation of this product, Texas Instruments has the type 502 bistable multivibrator. This silicon semiconductor network is in an hermetically-sealed package and is suitable for use in shift registers and binary counters. However, we expect the market requirements will be mainly met by the custom design of semiconductor networks.

Hi-Gain, Hi-Speed Transistor Switches

Two newly-developed diffused junction, drift field silicon mesa transistors, particularly designed for military applications have been announced by the Hoffman Electronics Corporation, 3761 So. Hill Ave., Los Angeles 7, Calif. Computers, data processing equipment for missiles and video amplifiers are some of the military applications made possible by the high gain and high frequency characteristics of the new transistors.

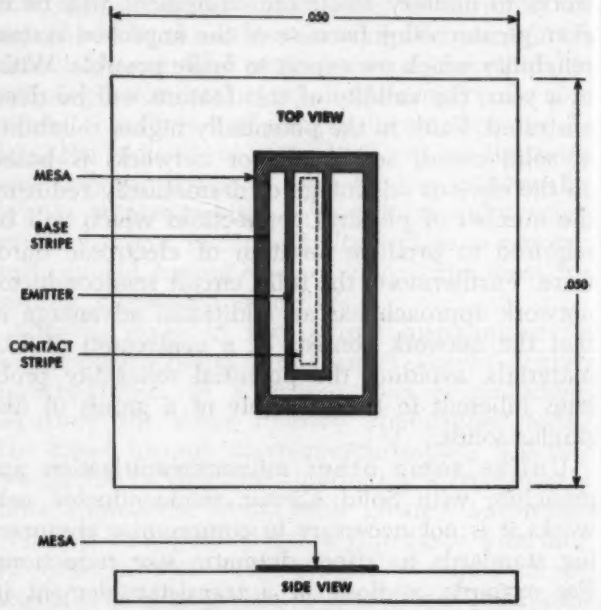


FIG. 1. PHOTOGRAPHIC fabricating techniques and unique configuration are credited with superior gain at high frequency of new silicon mesa transistors.

FIG. 2. U-SHAPED base-emitter pattern is seen in relation to transistor proper prior to hermetic sealing. New units are designed as high-speed switching units at medium power levels and as very high frequency amplifiers.

Using a unique, U-shaped base emitter configuration (Fig. 1) fabricated by exclusive photographic techniques, greater precision of geometric control and more uniform characteristics are claimed than have previously been achieved in similar type transistors. The transistors are pre-aged at 300°C before hermetically sealing into an inert gas atmosphere to stabilize the electrical parameters (Fig. 2).

Both transistors are basically control devices for small-to-large signal switching amplification, differing only in a higher dc pulse current gain in the 2N697, measuring a minimum gain of 40 and a maxi-

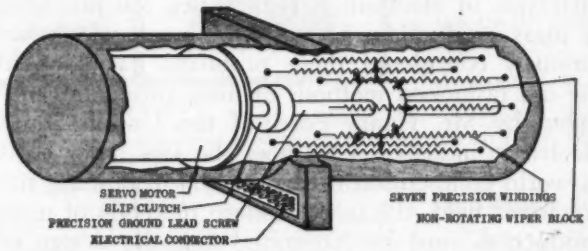
mum of 120 compared to a minimum of 20 and a maximum of 60 in the 2N696. Because of this unusually high small-signal current gain, either of the devices will replace up to three transistors of the same classification in many circuit applications. Minimum high-current gain is 6 or more at 20 mc, nearly three times the gain of 2.5, usually available from comparable units at this frequency.

Other characteristics include total power dissipation of 2 watts at 25°C case temperature, max collector-base voltage of 60 v, collecter-emitter voltage of 40 v and an emitter base voltage of 5 v.

FOR MORE INFORMATION CIRCLE 101 ON READER-SERVICE CARD

Servo-Driven Multi-Gang Potentiometer

New flexibility in applications design is seen as a result of the Model 801 Servo Driven potentiometer which employs up to seven precision straight-line resistive elements to simultaneously achieve control, feedback and a number of telemetry or functional outputs.



SEVEN PRECISION Pots are simultaneously driven by miniature servo motor. Linear and non-linear elements may be combined to meet customer's requirements, in 1⅞" x 8" package.

The integral sealed package contains, in addition to the precision resistive elements, a servo motor and a precision-ground leadscrew supported by Class 5 bearings and limited by slip clutches to prevent damage from overtravel. The input function of the servo motor is converted to a linear motion through a standard gear train to the headscrew which can accommodate various ratios. Standard gear ratios may be provided, or the gear train may be omitted for many applications.

The straight wire-wound resistive elements provide linearities of ±0.1% to ±0.25%, obtainable in the past only in large diameter potentiometers. Each individual potentiometer can be supplied with its own independent function, such as linear, non-linear or tapped to meet individual requirements.

Dry nitrogen is hermetically sealed in the unit to provide long shelf life and to prevent oxidation. Sealing also permits operation at unlimited altitude and meets the humidity, salt spray, fungus, sand and dust requirements of MIL-E-5272A. Operating temperature range is —40° to 165°C, vibration 10 C to 2000 cps, shock 60G in 11 msec, and an operating life of 2 million transversals. (*From 2-page Engineering bulletin* 801, *Bourns, Inc., Riverside, California.*)

FOR THIS LITERATURE CIRCLE 102 ON READER-SERVICE CARD

Economic Factors in Microcircuit Design

SAM GRIFFIN,
Microcircuit Div., Hi-Q Div.
Aerovox Corporation

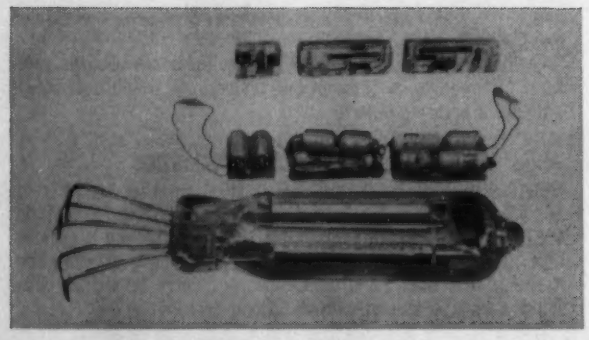


FIG. 1. BINARY INDICATOR comprises multivibrator (right) employing 11 components; a binary divider (center) with 14 components and lamp driver (left) using 9 components. The tiny Sylvania lamps, flashing at 2 & 4 cps, connect to the circuit. Scale is shown by subminiature vacuum tube.

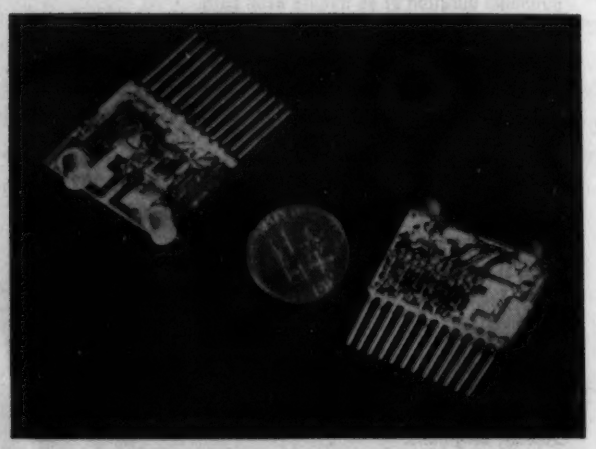


FIG. 2. HIGH SPEED TRANSFER CIRCUIT, for computer includes, 12 terminals, 2 transistors, 7 printed resistors and 11 conventional diodes on a 1" x ¾" x 0.030" steatite plate.

FIRST steps in ultra miniaturization of electronic circuits began with the development and application of titanate dielectrics before WW II. These made possible the first significant reduction in the size of electronic elements. Further extension of this work naturally lead to the application of resistor-forming material on the dielectric, achieving resistance-capacitance circuits of simple configuration. The resulting pieces, of course, were not microcircuits in terms of today's meaning but did give a significant improvement over resistance capacitance circiuts employing the conventional dielectric and resistance materials available at that time.

The "RC" couplates" first appeared before WW II. They were not used, however, until 1946, even though the first thoughts of compact lightweight electronic equipment were generated by aircraft requirements, because of the even greater wartime need for large quantities of proven components. Subminiature vacuum tubes and early missile development in the early years after the war further developed the concept of compact circuits. However, civilian and commercial requirements generally were overriding in the considerations of most firms, and research in the compact circuit area developed slowly.

The transistor was the first significant step toward microminiaturization after the development of titanates. The elimination of filament power and the order of magnitude reduction made possible in "B" power requirements sparked imaginations everywhere, but still there existed no overriding requirement for microminiature circuitry to dramatize its advantages. As the characteristics and capabilities of the transistor were being improved in the years before Sputnik, ideas about the structure of microcircuitry were quietly being tried out, changed and abandoned for lack of an urgent dramatic need.

An orbiting satellite furnished the trigger, all the hidden ideas came tumbling out, and new ones were created as well—a micro-"tinkertoy module," tiny printed circuit boards, and microminiature components of conventional configurations, such as smaller tantalum capacitors and ceramic capacitors. Micro-diodes and micro-transistors were soon available. Giant steps toward the future were proposed in the form of "molecular" circuitry, and combinations of these ideas and conventional circuitry are currently being developed and promoted.

In all this confusion, there seem to be few ties to the realities of modern day production requirements and the methods already developed for meeting these requirements.

Most approaches to the problems of microminiaturization of electronic circuitry beg the problems of mass production. The one approach which has seriously considered these problems has adopted the old fashioned methods of mass production initiated by Mr. Henry Ford. If the United States electronic industry is to meet the low labor costs in world competition in the rapidly expanding microcircuit field, the most modern methods of mass production must be integrated into the design of microminiature circuits.

Early mass production methods utilized a physically standardized *end product* so that a routine of simple operations could be established and performed with a low degree of skill, and so that machines could be made to handle these standardized parts which made up the standardized end product. Modern production methods employ standardized *processes* for the production of parts having non-standard configurations which allow the manufacturers to furnish his customers with a product exactly suited to their individual needs within the state of the art. Thus, the application of modern mass production methods is seen as the next great forward step in microcircuitry progress.

Major considerations in design and development of microminiaturized circuit packages are the structure, components, and interconnections. This is not to say that other considerations, such as the dissipation of waste power, are not important, but rather that this is primarily a final equipment problem in thermodynamics which, if solved efficiently, will provide an end equipment with a component density approaching that of the individual circuit packages.

The supporting structure of a microcircuit package is of primary importance since it forms the mutual coupling, both physically and electrically, between all components and interconnections. The structure must, in addition to the performance of its function of maintaining a fixed-physical and

electrical relationship between each of the components and the electrical interconnections, be capable of assuming a wide variety of physical configurations to meet the great majority of forms demanded by equipment designers. Yet, the processes for producing the structure must be standardized to permit low fabrication costs. The combination of ceramic plates and transfers of molded epoxy are well suited to meet these requirements. Methods are now available for rapid, relatively inexpensive, forming of cramic plates in large or small quantities. So-called temporary epoxy transfer molds can be quickly and easily made to provide highly accurate finished pieces.

Concerning the miniaturization of components it has been said that they are already so small that we do not know how to use them. That this is true is evident from the unanswered question: How is the waste heat to be removed without losing a major portion of the size reduction currently provided by present microminiature components? Component densities of 2000 parts per cubic inch have already been achieved in digital computer circuitry (Fig. 1) through the use of printed resistors; Cerafil*, Cerol*, and tantalum capacitors; micro diodes and the Raytheon subminiature transistors. The application of PSI (Pacific Semiconductors, Inc.) micro transistors to this circuit configuration will increase the component density by more than four times.

Influence of Economic Production Techniques

Thus, it is now time to turn our attention to the economic production of already completed developments. The same equipment used in the construction of this small (3/16″ X 1/8″ X 3/8″) circuit package is producing the medium density circuit packages shown in Fig. 2. Wide production latitudes are permitted by this technique.

Many developments in thin film resistors involve great skill and expensive equipment in their manufacture. These provide superior performance characteristics such as very small temperature coefficients, very low current, noise immunity to moisture, and high stability. As yet, however, all these desirable characteristics are not available at the same time over the full range of resistance desired. Also simple screen-printed composition carbon resistors which can be produced on low-cost high-production-rate equipment are available with performance characteristics better than the conventional composition carbon resistor found to be satisfactory in so many circuits.

The temperature characteristics of resistors printed on small substrates range between 800 to 900 parts per million for values from 100 ohms to two megohms per square; and when the effects of temperature equalization afforded by close proximity on a relatively good conduction medium are considered a great many of the requirements for low T-C resistors are eliminated. The load life characteristics of these resistors is about 1.5% to 3%

*Aerovox Corporation Trademarks

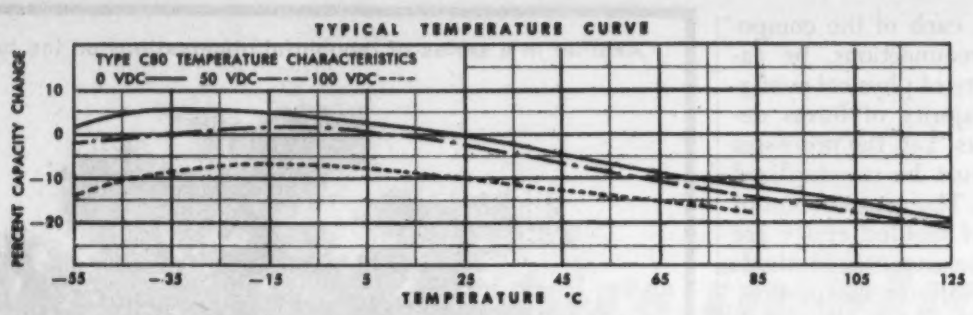


FIG. 3. TEMPERATURE CAPACITY CHARACTERISTIC, Cerafil capacitors. By combinations of elements with different ceramic formulations, other characteristics can be tailored to order.

change in one thousand hours under load densities of 20 watts per square inch at room temperature for 100 hours. These data were obtained with four 0.01 square inch resistors on a ¼" X 1" ceramic plate. Such resistors must be protected from humid conditions and this is one of the roles of the epoxy structure.

Resistors exactly like those used for determining the load life characteristics were subjected to both the standard military humidity cycle and the moisture resistance cycle. A change of 2% to 3% occurred in humidity and no change was observed from the moisture cycle. Temperature cycling caused a permanent change of only 0.3%. Resistance tolerances of 1% are economically feasible while 5% tolerances are commonly specified. Voltage coefficients are well below 0.05%/volt. The current noise of these resistors is somewhat lower than conventional compressed carbon resistors.

Further development is proceeding toward the use of a glaze as the resistance element. Preliminary results have shown temperature coefficients of less than 50 parts per million, significant improvement in load life characteristics, and immunity to humid conditions without protection. At this time, however, current noise is slightly greater than the conventional compressed compoistion carbon resistor.

Many recent developments in the capacitor field provide reliable production-designed components. In the micro-micro-farad range the Cerafil capacitor gives superior performance in the smallest volume.

The obstacle of fragility of very thin ceramic sections has been circumvented by employing the Cerafil design and technique. The basic principle consists of forming the thin film of ceramic dielectric on a cylindrical substrate, which is one of the electrodes and also serves as a support for the fragile film. With this support, extremely thin dielectric films can be processed conveniently and thus high capacities obtained. The thickness of the film employed determines the voltage rating. A capacitor rod element is approximately 1/32" in diameter with a length determined by the length of the unit desired. The outer surface of the dielectric film is also metallized forming the second electrode.

The Cerafil design concept, in addition to its miniaturization features, also lends itself mechanization and accurately controlled production because of the simplicity of the process involved. The process of dielectric formation and deposition produces a very uniform and homogeneous film structure, necessary for high dielectric strength. These features make feasible the economic production of close-tolerance, reliable units in large quantities.

Besides providing support to the fragile thin ceramic film, Cerafil design offers several additional advantages. Circuits printed on the ceramic plate can be bridged, generally providing higher density designs. Parallel connection to obtain higher capacities becomes a relatively simple operation. Also in this construction, elements having different characteristics can be combined to obtain a resultant characteristic. For example, an element of positive temperature coefficient may be paralleled with one of a negative temperature coefficient to give a flat characteristic.

The capacitance values available in single rod Cerafil units used in microcircuit designs range from 10 to 5000 $\mu\mu$f. The temperature and voltage coefficients are shown in Fig. 3. Power factor is 2.5% maximum and insulation resistance is 100 megohm-μf or 10,000 megohms whichever is smaller. Capacity tolerances as low as ±5% are available although ±10% and ±20% are commonly used. The capacitors are flash tested at 300 volts.

Where larger values of capacitances in the fractional microfarad range are required, especially where non-polar units are necessary, the Cerol capacitor provides superior performance in the smallest volume. Fig. 4. shows applicable temperature and voltage characteristics. These units are usually shaped as required to obtain the highest volume efficiency in each particular microcircuit design, providing a 20 μf capacity per cubic inch.

The Cerol capacitor is produced by a process which permits the rolling of an extremely thin ceramic dielectric film upon which a precious metal is deposited. The rolled ceramic film is then fired to form a compact and monolithic structure capable of withstanding severe environmental conditions. These units are produced by methods similar to thise used for metallized paper capacitors.

Tantalum capacitor data will not be given here since many manufacturers furnish slightly different data. Generally, the smallest unit with adequate performance is chosen or the purchaser may wish to specify the unit to be used.

Diodes and transistors are selected in accordance with purchasers' specifications. Where more expensive units are justified and where the micro diodes and micro transistors having the desired characteristics are available, the PSI units are used (Fig. 5). Where price, time, or performance characteristics are of primary importance, the units specified by the purchaser are used. Many times it is to his advantage to furnish these semi-conductors either because of experience with particular units or because of availability and/or price.

The interconnections internal to the microcircuit package are as important as the external ones. Both contribute to the reliability and volumetric efficiency of the end equipment. The printing of conducting paths and resistors reduces the number of junctions between elements and so contributes directly to the reliability of the equipment. The

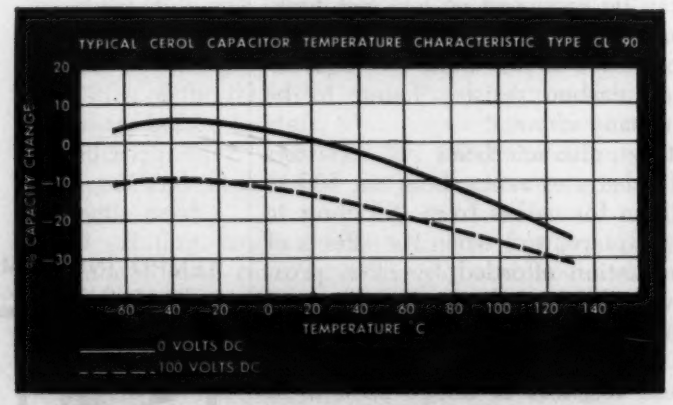


FIG. 4. TYPICAL T-C CHARACTERISTIC of Cerol Capacitor Type CL 90.

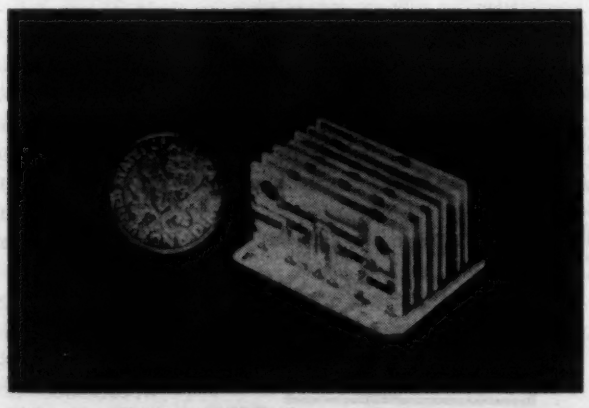


FIG. 5. FULL ADDER for space-borne computer contains 85 components in ½" x ⅝" x 1" volume.

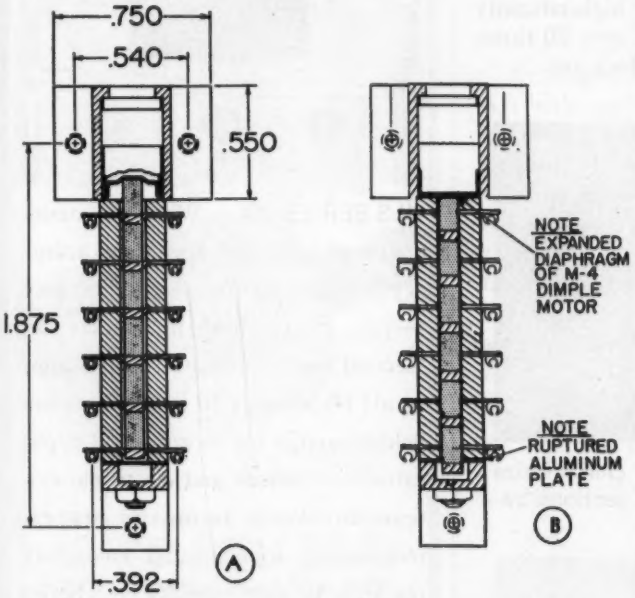
versatility shown by the different circuit configurations illustrates the adaptability of the technique to external connector designs. Terminals have also been brought out normal to the plate surface. Transistors and diodes are replaceable.

The microcircuit concept has now reached the stage where production considerations have become paramount. Typical microcircuit designs, employing the structure and components herein described, are responsive to these considerations and are economically practicable.

FOR MORE INFORMATION CIRCLE 103 ON READER-SERVICE CARD

Six-Circuit Explosive Switch

A six-pole normally-closed switch for simultaneous opening of circuits in missiles or similar applications requiring high reliability, has a capacity of 10 amperes per circuit, although it measure only 2" x 1" x 9/16" wide, and weighs only 1½ oz. (Fig. 1).



DIMPLE MOTOR actuates 6-pole high reliability switch for missile actuation, controlling six 10-ampere circuits with weigh of only 1½ oz. View A, switch in NC (unoperated) condition; view B, operated condition, all circuits open.

The switch operates in about 5 milliseconds, being powered by an M-4 dimple motor. When the motor fires, its internal gas pressure expands a diaphragm, causing the shaft to move forward, breaking all six circuits. The motor delivers a force of 10 lbs to operate the switch and to rupture a frangible aluminum disc at the end of the switch shaft which prevents premature operation of the switch under severe shock.

Approximately 5 vdc will fire the motor, but in its first application it was actuated by the discharge of a 0.68 mfd capacitor, charged to 38.5 volts. Designated the XM-9 switch, it operates normally within temperatures from —65 to 160°F and withstands centrifugal accelerations up to 1000 G. Circuits remain closed or open under severe vibration. The switch is a development of Dial Service and Manufacturing, Inc., 1741 Rockwell Ave., Cleveland, Ohio, based on a design by the Diamond Ordnance Fuze Laboratories.

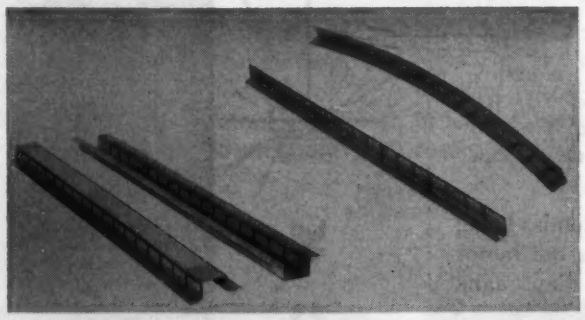
FOR MORE INFORMATION CIRCLE 104 ON READER-SERVICE CARD

Damping for "White Noise"

A new damping material having high efficiency for controlling the resonant response of structures exposed to high-frequency vibration, and wideband noise experienced in super-sonic jets, and missiles has been developed by the Lord Mfg. Co., Erie, Pa. The new material, designated Dyna-damp, employs a specialized form of Lord's BTR (broad temperature range) elastomer which is said to maintain excellent damping and environmental resistance characteristics over temperatures from —65° to 250° F. Temperature sensitivity at both ends of the scale has been a major limitation of previous damping materials.

First announced in 1959, Dyna-damp structural sections have since been supplied to most major airframe and missile contractors for their evaluation. Although these tests are not complete, results so far indicate that the material holds great promise for combating acoustic fatigue and structural response. Life of a Dyna-damp panel tested under high-intensity sound fields to 170 db has proved to be over 20 times that of solid aluminum sheet of equal thickness.

HIGH Damping efficiency, long life characterize Dyna-damp panels. Typical fabricated sections below.



Dyna-damp laminated panels consist of plies of metal plates with BTR elastomer sandwiched between, and bonded to the plates (Fig. 1). The plates can be sheared, punched and formed by the usual stretch-forming techniques employed in the aircraft industry (Fig. 2). Produced in hat and angle shapes, and with approximately 60% the strength of solid aluminum, these formed sections applied to structural panels materially reduce resonant response to "white" noise and vibration. Alternatively, the Dynadamp sections can themselves be used as damped load-bearing beams. Technical Data on the Dyna-damp materials is contained in the Lord Engineering Report 325.

FOR THIS LITERATURE CIRCLE 105 ON READER-SERVICE CARD

Missile Test Transducer

New Crescent type KB rectilinear transducers (Fig. 1) are ac electro-mechanical bridge type units designed to sense linear position for measurement and control by utilizing the variable permeance principle. Five models, from 2" to 9½" in length, cover linear ranges of ¼" to 4". The total mechanical stroke exceeds the rated range to avoid damage from overtravel when the entire range is used.

FIG. 1. RECTILINEAR transducers have a threaded ½" diameter body which can be screwed into a mounting fixture like a bolt, then rotated to a null position and secured by locknuts.

Developed for use in testing missile engines, type KB withstands rapid environmental changes over temperatures from —160°F to 450°F, and are applicable in many airborne and industrial applications. Designed for operation with a maximum input of 24 v rms, 3000 cps; if the transducer is operated at other frequencies, slight changes from rated values will be observed in maximum excitation voltage, phase shift and linearity. Rated phase shift is less than 10° with 3 kc carrier, and non-linearity is less than 0.5% over the rated range.

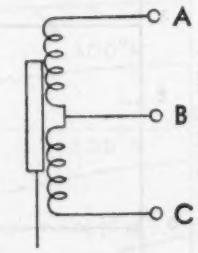


FIG. 2. INTERNAL Wiring Connections, Type KB Transducer.

The null point of the bridge-type (Fig. 2) circuit can be shifted by adjusting the impedance ratio between the reference arms of the bridge circuit. A two-arm inductive or resistive device is used as the reference half of the bridge.

In operation, movement of the sensing probe to either side of null causes an output voltage to occur across the bridge. Magnitude of this voltage is linear with probe displacement and reverses phase 180° at the null position. The working portion of the probe is magnetic stainless steel, with the probe extension made of non-magnetic stainless. An integral Viking connector which accommodates three #20 contracts and is rated for continuous operation above 450°F is furnished with each transducer. The KB transducer is a development of the Crescent Engineering & Research Co., 5440 No. Peck Rd., El Monte, Calif., and is hermetically sealed by encapsulation of its coils in an inert epoxy resin.

FOR MORE INFORMATION CIRCLE 106 ON READER-SERVICE CARD

SYSTEM DESIGN USING BACKGROUND-LIMITED IN

The signal-to-noise ratio of modern infrared photon detectors is limited by the statistical fluctuations in the incident flux. Data are given for lead selenide and copper-doped germanium, as examples. By design of the optics-detector assembly to take full advantage of these detector characteristics, nearly the ulimate performance of a system can be attained. The required design concepts are outlined, and an example is given of the performance which may be expected from an optimized pulse-type system. **Dr. Swift is head of Interceptor System Research, Santa Barbara Research Center, Goleta, Calif., a subsidiary of the Hughes Aircraft Co.**

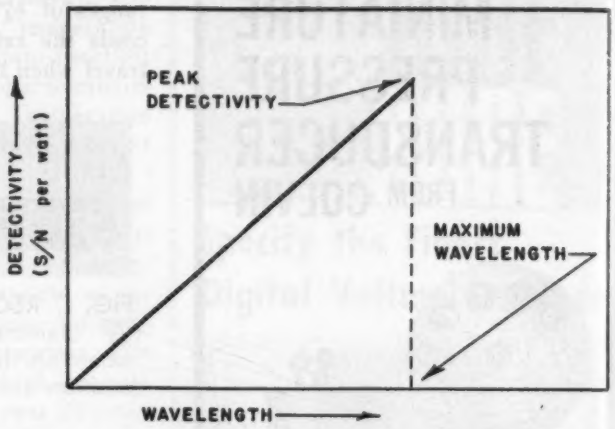


FIG. 1. **IDEALIZED** photoconductor response curve.

THE PERFORMANCE of a well designed passive infrared system using modern detectors is limited by the generation and recombination noise in the detecting element. If the detector is operated at a sufficiently low temperature, generation of carriers in the detecting element is dominantly due to photon excitation. As a result, the detection and tracking range of a system is determined in the ideal case by the equivalent temperature of the background against which a target appears. By proper design of the optics—detector assembly, this ideal performance can be closely approached. The performance gains obtainable by these design concepts are particularly significant for cold body detection in space applications, where the background temperatures are very low.

In order to outline the system design concepts required to take full advantage of background-limited infrared detectors the fundamental characteristics of such detectors must be clearly understood. These characteristics are described, and typical detector measurement data are presented. These data illustrate the degree to which presently available detectors approach this theoretically ideal radiation transducer.

A general performance equation is given for a pulse-type system using background-limited detectors, followed by a discussion of the significant factors to be considered in the design of an optimized system.

Finally, an example is given of the performance which can be achieved by this approach.

BLIP Detector Characteristics

The term "BLIP" detector refers to a Background-Limited Infrared Photoconductor. This term was originated by Burstein[1,2] and is discussed by Petritz[3]. The electrical conductivity of this ideal transducer is determined only by the incident photon flux on the detector; i.e., the rates of thermal and impact ionization of carriers are negligible in comparison with those from photon ionization.

By present engineering convention, the quality of a detector is characterized by its spectral detectivity[4], $D^{\star}(\lambda)$. This quantity is defined as the rms signal-to-noise ratio produced in a one-cps electrical bandpass amplifier, when a detector one cm^2 in area is illuminated by one rms watt of sinusoidally-modulated radiation at wavelength λ. In over-simplified terms, it is the signal-to-noise ratio per watt of incident radiation.

The detectivity of a BLIP detector** is given by

$$D^{\star}(\lambda) = \frac{\sqrt{\eta}\lambda}{2hc\sqrt{J_B}}$$

$$= (2.52 \times 10^{18}) \frac{\sqrt{\eta}\lambda\,(\text{microns})}{\sqrt{J_B}} \text{ cm } (\text{cps})^{1/2}/\text{watt} \qquad (1)$$

where: h is Planck's constant; c is the velocity of light; J_B is the background flux (photons/cm^2/sec) on the detector of wavelengths less than the maximum, λ_m, for which the detector is designed; and η is the detective quantum efficiency, and would equal unity for the ideal detector. It is the ratio of the effective-to-incident photons.

The response of an ideal photoconductor is shown in Fig. 1. The value of the long wavelength limit is determined by the energy gap of the photoconductor material. The response is proportional to wavelength because the detectivity is defined as the signal-to-noise ratio per watt. The response in terms of signal to noise per unit photon flux would be independent of wavelength since photoconductors detect photons, not watts.

The detectivity of a cold BLIP detector with unit quantum efficiency (Equation 1) is shown in Fig. 2. The solid lines give the peak detectivity

**According to Petritz[3], the limiting detectivity of a photovoltaic detector is larger by 2 than this value for a photoconductor. This is because recombination noise is not believed to be present in the detector output.

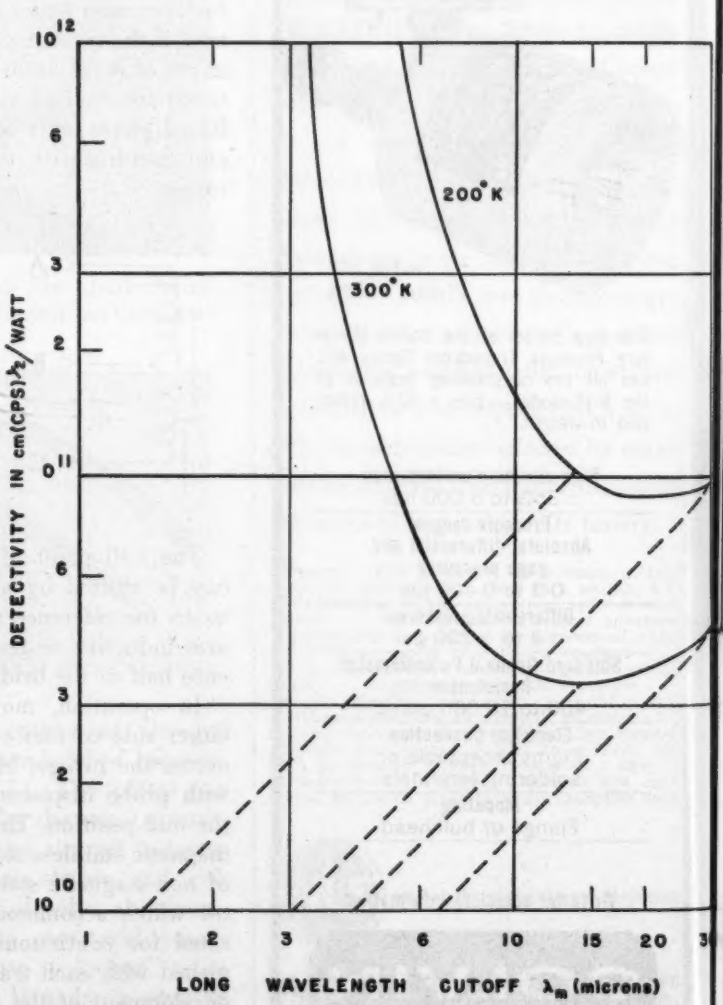


FIG. 2. **PEAK** detectivity vs. cut-off wavelength for a BLIP detector. Background flux is from a hemisphere at 200° and 300°K. Dashed lines indicate spectral detectivity for detectors having $\lambda_m = 14$ and 30 microns.

INFRARED DETECTORS

DR. I. H. SWIFT

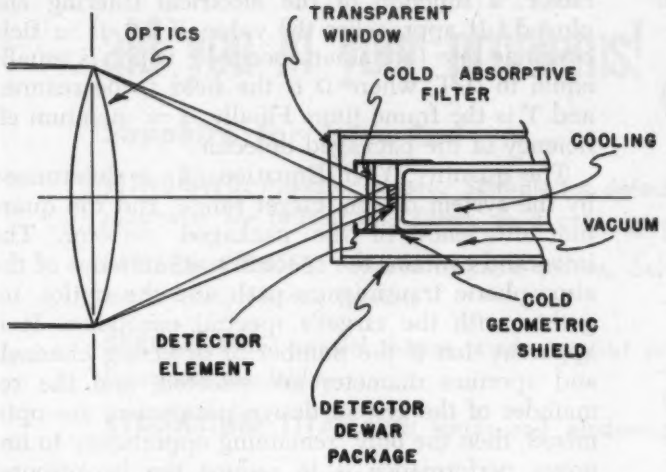


FIG. 3. RADIATION shielding techniques are effective in reducing background flux.

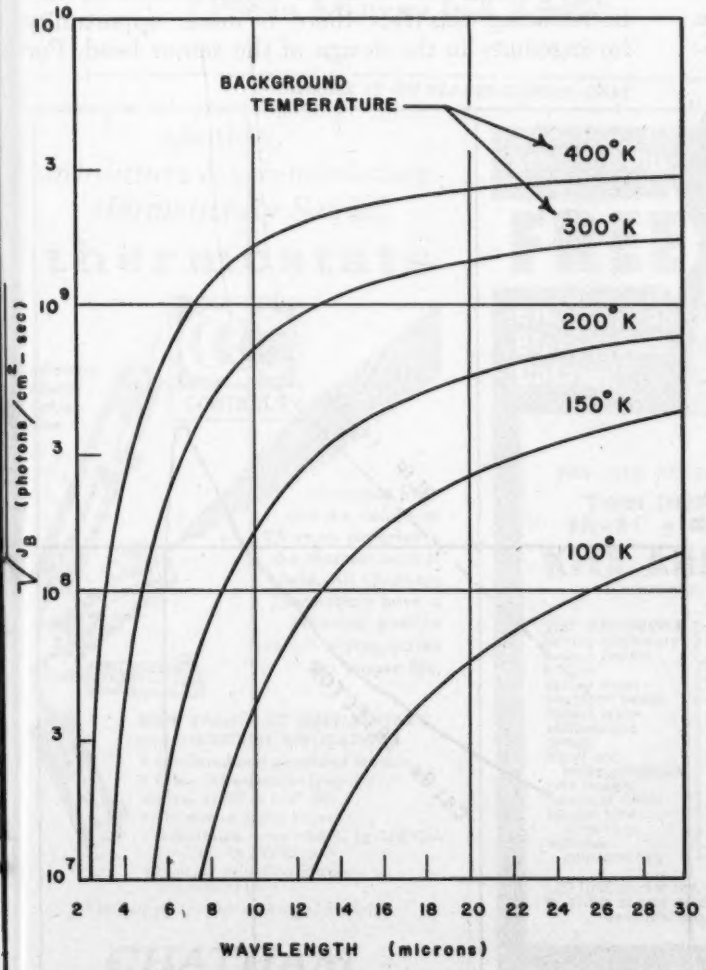


FIG. 4. SQUARE ROOT of the total photon flux from 0 to the indicated wavelength, with hemispherical field of view.

for a detector that "sees" background radiation from a hemisphere at either 300° or 200° Kelvin. The peak value is increased with lower background temperatures because the detector noise is proportional to the square root of the background flux. The peak value is also a function of the long-wave length limit, λ_m, for a similar reason.

It appears from Equation (1) that there is no limit to the detectivity which can be achieved. All that is needed to increase the signal-to-noise ratio is to reduce the flux on the detector, J_B. There is, however, an upper limit which appears when the constant background flux is reduced to less than the signal flux. At this point the signal-to-noise ratio of the signal photon stream is the controlling factor. For most design problems, however, the signal flux is many times less than the background flux on the detector.

Effect of Radiation Shielding on Detector Performance

Nearly all present-day infrared detectors, when adequately cooled, are background noise limited. Examples of such detectors are lead selenide, indium antimonide, and copper-doped germanium. The flux on the detector can be reduced by two radiation shielding techniques. The first is the use of geometric shielding, to limit the view so that the detector, ideally, receives radiation only through the optics. The second is wave-length shielding, which employs filters to eliminate radiation in non-useful wavelength regions. These techniques are illustrated in Fig. 3.

The effect of wavelength shielding can be determined from Fig. 4, where $\sqrt{J_B}$ is plotted for various background temperatures and detector long-wavelength cut-off. These calculations are based on the radiation received from a hemispherical field of view. The effect of geometrical shielding can be calculated from the half-cone angle of view, θ, permitted the detector by a cold opaque shield. The value of J_B used in Equation (1) is that obtained from Figure 4, multiplied by sine θ. It is interesting to note that sine θ is the numerical aperture of the optics, where θ is the half angle of the cone of focused radiation.

The effects of both geometric and wavelength shielding on the detectivity of lead selenide developed at the Santa Barbara Research Center (SBRC) are shown in Fig. 5. Similar results are obtained by radiation shielding of other types of detectors. Application of these techniques to an SBRC search-track system increased the signal-to-noise ratio of the lead selenide detectors by a factor of five. As a result, the detection and tracking range of this system was more than doubled.

The degree to which presently available detectors approach the ideal, or BLIP, detector, is apparent from recent measurements on copper-doped germanium. The spectral detectivity of this detector when operated at liquid helium temperature is shown in Fig. 6. Its peak response is at 25 microns. Fig. 7 shows the same detector used with a cold barium fluoride filter. With this filter, the peak response is at 14 microns—the appropriate value for a system operating in the 8- to 14-micron atmospheric transmission window.

Both Figs. 6 and 7 contain for reference the detectivity (dashed line) for a BLIP detector with unit quantum efficiency and having the same view angle as in the measurement experiment. Comparison of the measured and BLIP values shows that the signal-to-noise ratio averages 40 to 45% of the ideal value over the responsive wavelength region.

Fresnel reflection at the KRS-5 detector package window is 29%; 36% of the remaining photons are reflected at the first surface of the germanium crystal. These two effects in series constitute a 51% loss in incident radiation. An additional small loss is attributed to transmission through the germanium crystal. It is clear, then, that the detecting crystal utilizes the photons that enter it with nearly 100% efficiency, and the detector noise is that of fluctuations in the number of carriers produced by the photon excitation.

The reflection losses at the optical surfaces of the detector flask window and the germanium crystals can be greatly reduced in principle by the use of appropriate interference coatings. Assuming that 80% of this loss can be so avoided, the signal-to-noise ratio of a packaged detector would be increased from 45 to 70% of the BLIP value. This value corresponds to a quantum efficiency of 0.5, which is close to the ideal.

Decreasing the background flux, J_B, depresses the photon-excited generation-recombination noise, and eventually other noise sources will dominate. It is possible to evaluate this factor by considering that the detectivity of a copper-doped germanium detector has been increased tenfold over the values shown in Fig. 6. This was accomplished in the laboratory by employing radiation shielding techniques, and corresponds to a value of about 10^{15} photons/cm²/sec for J_B. This value is as low as can be achieved in the design of an optical collection system for viewing cold space; therefore the detector will be background limited for all applications of interest.

The Range Equation

A pulse-type system generates detector output signals by scanning the detector over the field of view. A point source of energy in the field of view generates a pulse when its image moves over the

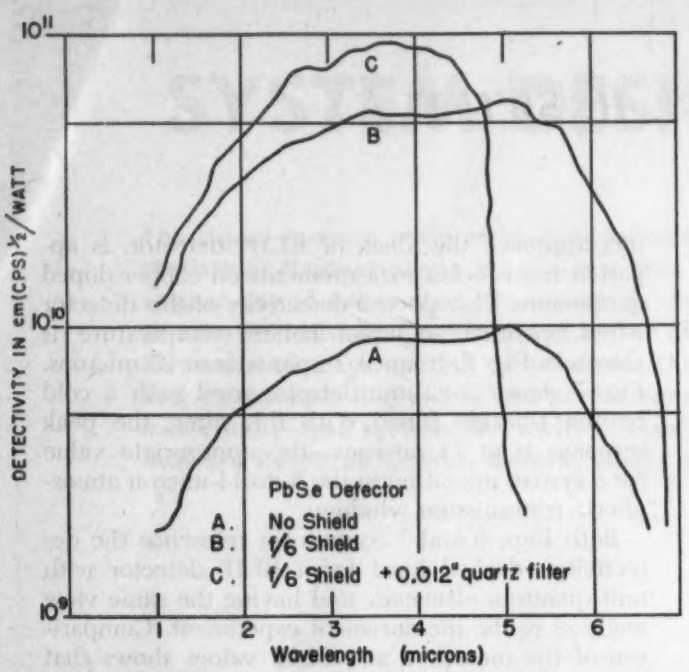


FIG. 5. EFFECT of geometric and wavelength shielding on the detectivity of SBRC lead selenide at 77°K. The extent of geometric shielding is indicated by the f/number, i.e. (aperture diameter)/(distance from detector).

detector. This type of system utilizes the information from the detector more efficiently than does the more conventional carrier-type (e.g., reticle) system.

The range equation for a pulse-type search system using background-limited photoconductors as detector elements can be readily obtained using Equation (1) and the results given in Reference 4. This gives

$$R^2 = \frac{V}{\sqrt{J_B}} \int_0^{\infty} T_a(\lambda)\ T_o(\lambda)\ H(\lambda)\ d\lambda \quad (2)$$

where

$$Y = \frac{\pi}{4} \frac{(NA)d}{V_p/V_n} \left(\frac{CV}{\dot{\Omega}}\right)^{1/2} \sqrt{\eta} \quad (3)$$

and where the symbols have the following meanings:

$T_a(\lambda)$ = spectral transmittance of the path between the detection system and the target; $T_o(\lambda)$ = spectral transmittance of the optics, including losses due to absorption and imperfect reflectance, and to blocking elements; $H(\lambda)$ = spectral emittance of the target (photons/seconds-steradian); λ_m = maximum wavelength of photoconductor response; J_B = background flux (photons/cm²-second) on the detector package in the wavelength range 0 to λ_m; V_p/V_n = ratio of peak signal pulse to rms noise voltage. The value of this ratio depends on the required detection probability and the tolerable false-alarm rate; (NA) = numerical aperture of the optics, including the condenser, if any; d = diameter (cm) of entrance pupil of optics; R = range to target (cm); C = number of independent detector channels, assuming all detectors used 100 percent of the time; V = visibility factor, a function of the electrical filtering employed.[4] It approaches the value of 2.0. $\dot{\Omega}$ = field coverage rate (steradians/second), which is usually equal to Ω/T, where Ω is the field to be scanned and T is the frame time. Finally, η = quantum efficiency of the packaged detector.

The quantity, Y, in Equation (2) is determined by the system design, target range, and the quantum efficiency of the packaged detector. The integrand contains the spectral transmittance of the atmospheric transmission path and the optics, together with the target's spectral emittance. It is apparent that if the number of detecting channels and aperture diameter are selected, and the remainder of the system design parameters are optimized, then the only remaining opportunity to improve performance is to reduce the background flux, J_B, on the detector.

It is clearly important that the background flux on the detector be minimized as this is the only fundamental limit on performance, other than the statistical fluctuations in the signal photon stream. In reducing this flux there is much opportunity for ingenuity in the design of the sensor head. For

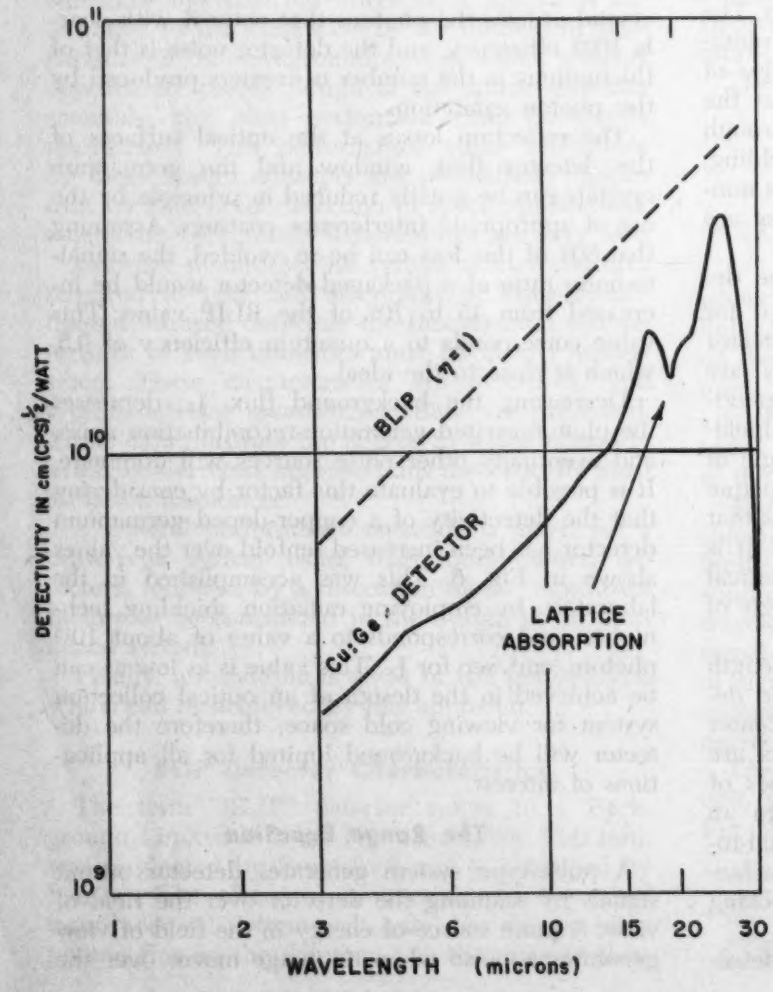
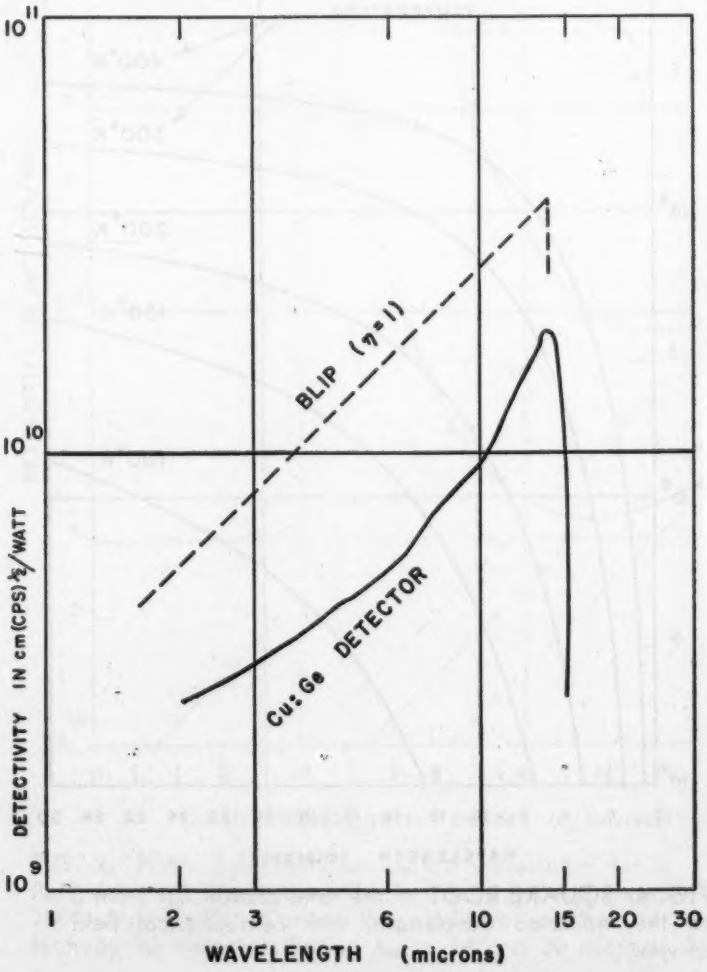


FIG. 6. DETECTIVITY of SBRC copper-doped germanium detector measured at liquid helium temperature, with 97° cone angle field of view of room-temperature radiation and an infrared window of KRS-5. Also shown (dashed line) is curve for a BLIP detector with $\eta = 1$, having same 97° field of view and a background temperature of 300°K.

FIG. 7. DETECTIVITY of copper-doped germanium detector with cold barium fluoride filter and KRS-5 window. The upper curve is for a 14-micron BLIP detector, with same field of view (120°) and 300°K background.



an airborne application the equipment might be flying at high altitude, such as 70,000 feet, where the ambient air temperature is about 225°K. The detector will receive background flux from the emission of atmospheric constituents, the optics, and optical supporting members. If all of the sensor head components are operated at the ambient air temperature, instead of being warmed, J_B will be reduced.

Other design measures can also be employed in varying degrees to reduce J_B. Some of these are:

1. Provide cold geometrical shielding in the detector package to limit the acceptance cone angle for radiation to the minimum which is necessary. Ideally, the detector should be restricted so as to see out only through the optics. With finite detector area this can be done by either placing the cold field stop at the entrance aperture, or by reducing the effective aperture diameter below that physically available.
2. Restrict the wavelength region "seen" by the detector to only those portions where the contribution of signal energy outweighs the degradation due to additional background flux. For example, operation in the H_2O or CO_2 absorption bands probably is detrimental to performance.
3. Minimize the emissivity of reflecting surfaces of the optics.
4. Minimize the emissivity of detector flask window.
5. Reduce to a minimum the solid angle subtended at the detector by optical support members.
6. Block the view of supports, etc., from the detector by portions of spherical mirrors, with the center of curvature of these shielding mirrors placed at the detector.

Design Example

In order to illustrate the design concepts described, the range equation (2) may be used to evaluate the performance of an infrared sensor. Simplifying assumptions are made in order to prevent obscuration of the significant factors.

A system operating in the 8- to 14-micron atmospheric window is to detect a 300°K (27°C) blackbody target which is one square meter in area. It is assumed that the target is above the atmosphere and that the sensor "sees" it through the atmosphere by its contrast against cold space. Thus the target signal is attenuated ($T_a = 0.8$); but more significantly, the atmospheric radiance of the transmission path will generate noise in the detector.

The following parameter values have been used: Aperture diameter—60 cm or two feet; optical transmission—60% due to blocking of aperture by the secondary mirror; required signal-to-noise ratio (V_p/V_n) = 5; number of detector channels, C = 5; pulse visibility factor of the electronics, V = 1.6; and the quantum efficiency of copper-doped germanium detector, $\eta = 0.5$. The field scanning

New Series of Indium Antimonide Infrared Detectors by Radiation Electronics Co.: l. to r.–PC-02, A-04 (J-02 same dewar as PC-02).

Indium Antimonide Infrared Detectors

PHOTOVOLTAIC detector, Model J-02, operates at liquid nitrogen temperature and exhibits high sensitivity from the visible region to 5.7 microns. Because of its very small area (0.1 × 0.1 mm²), fast response, and sensitivity, the J-02 detector permits the design of infrared systems with high optical gain, high resolution, and very rapid scanning rates. Impedance is approximately 50,000 ohms. The J-02 is efficiently coupled to both transistor and vacuum tube preamplifiers. Linear arrays of detection elements can be fabricated for special applications.

PHOTOCONDUCTIVE detector, Model PC-02, operates at the dry ice point with sensitivity from the visible region to 6 microns. The PC-02 is conveniently coupled to both transistor and vacuum tube amplifiers. Standard detector area is 1 × 1 mm²; other detector areas available from 0.5 × 0.5 mm² to 2 × 2 mm². Time constant less than one microsecond.

PHOTOELECTROMAGNETIC (PEM) detector, Model A-04, operates at ambient temperatures and does not require bias supply. Sensitive from the visible to seven microns with a time constant of less than one microsecond. Standard detector element is 1 × 1 mm², and other sizes from 0.5 × 0.5 mm² to 2 × 1 mm² can be furnished. Normally used with an input transformer for efficient coupling to transistor or vacuum tube amplifiers. Housed in a hermetically sealed, ruggedized package, the A-04 is supplied with a magnesium oxide window. Other window materials, such as sapphire or arsenic trisulphide, are also available.

Radiation Electronics Company also manufactures high speed radiometers, industrial radiation thermometers, thermal scanning devices, blackbody reference sources, and low noise preamplifiers. Prompt attention will be given to your special problems by our experienced scientific and engineering staff. Contact RADIATION ELECTRONICS COMPANY, Division of Comptometer Corporation, 5600 Jarvis Avenue, Chicago 48, Illinois. Dept. M5.

SPECIFICATIONS

	PEM	PHOTOCONDUCTIVE	PHOTOVOLTAIC
Operating Temperature	20°C	−78°C	−196°C
NEP* (500°K), watts	3.3×10^{-9}	1.5×10^{-10}	7×10^{-12}
NEP* (5 microns), watts	1×10^{-10}	3×10^{-11}	1.4×10^{-12}
Spectral Cutoff, microns	6.9	6.1	5.7
Sensitive Area, mm²	1 × 1	1 × 1	0.1 × 0.1
Time Constant, microseconds	< 1	< 1	< 1
Typical Resistance, ohms	5	100	50,000

*1 cps bandpass at 500 cps

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rate chosen is a 10° square field in one second, or $\dot{\Omega} = 0.03$ steradian/second.

To compute detection range from Equation (2), the constant flux, J_B, on the detector must be determined. It is assumed that all of the design measures listed have been employed. The detector will then "see" the atmospheric radiance value which is within the instantaneous field of view, added to the emission from the two mirrors of the reflective optical collector. These two radiance contributions will be "seen" over the solid angle of the focused rays on the detector. Thus the total flux on the detector can be represented approximately by

$$J_B = (NA)^2 \int_{8\mu}^{14\mu} [R_a \epsilon_a + R_m \epsilon_m] \, d\lambda \quad (4)$$

where the R's are blackbody spectral radiance values (photons/cm²/sec); the ϵ's are emissivities; and the subscripts a and m refer to the atmospheric path and mirror, respectively.

If Equation (4) is substituted into Equation (2), the numerical aperture (NA) of the optical collector cancels out. Thus the optical speed of the collector is unimportant. For this to be true, three conditions must hold; a) the detector must "see" only through the optics; b) the detector is background limited; and c) the system is detector-noise limited.

Returning to Equation (4), it has been assumed that within the 8- to 14-micron window the atmospheric radiance can be represented by an equivalent blackbody temperature and an emissivity, as was done for the mirror. If the temperature of the mirror and atmosphere were the same (say 300°K), then $R_a = R_m$, and this value can be obtained from Fig. 4.

Equation (4) then shows that the system performance is limited by the sum of the atmospheric and mirror emissivities. With the sensor looking up from the operational altitude of an aircraft, the mirror emissivities will likely dominate. At ground levels, atmospheric radiance will govern performance.

The range can be computed from Equation (2) using the chosen parameters and $\epsilon_a = 0.1$ and $\epsilon_m = 0.05$, which are reasonable values. The range is 90 miles, for a signal-to-noise ratio of 5 from a one-square-meter target at 300°K. This performance is equivalent to detection of the thermal radiation of a refrigerator ice cube at three miles range.

References

1. E. Burstein, G. S. Picus, and N. Sclar, PHOTOCONDUCTIVITY CONFERENCE (John Wiley & Sons, Inc., New York 1956), pp. 353-413.
2. E. Burstein and G. S. Picus, "Background Limited Detection", paper presented at IRIS, February 3, 1958.
3. R. L. Petritz, "Fundamentals of Infrared Detectors", *Proc. IRE*, Vol. 47, No. 9, pp. 1458-1467.
4. Pronounced "Dee-Star". See "Response and Detecting Ability of Radiation Detectors," by R. Clark Jones, *Proc. IRE*, Vol. 47, No. 9, p. 1498, for further clarification of the term *detectivity*.
5. R. H. Genoud, "Infrared Search System Range Performance", *Proc. IRE*, Vol. 47, No. 9, pp. 1581-1586.

Ultra-Precision Selector Switch

Designed specifically for applications requiring a small unit, low friction torque, high accuracy and low electrical noise, this precision switch is packaged in a standard #10 synchro housing. Its clean, neat design incorporates a precision slip ring-commutator, made possible through Electro Tec's patented electrodeposition process.

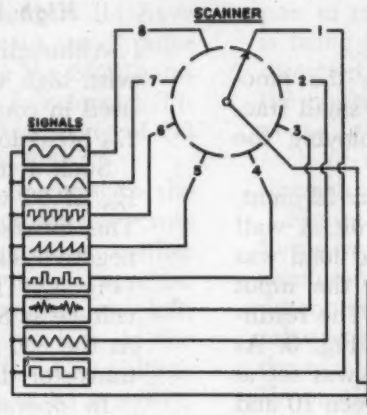


FIG. 1. TYPICAL SCANNER application operates with negligible brush bounce to 20,000 switches per minute.

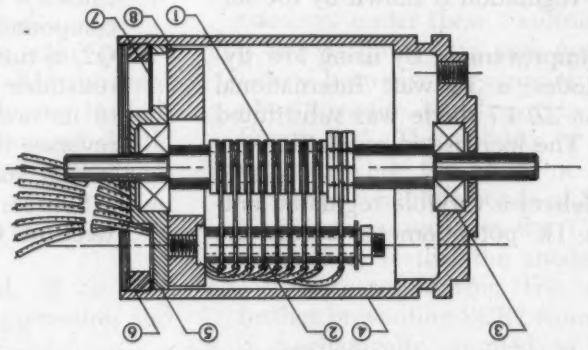


FIG. 2. LOW-TORQUE SWITCH construction in #10 synchro case includes: (1) Slip ring and commutator assembly, (2) brush block, (3) precision ball bearings, (4) housing, (5) end plate, (6) retaining ring, (7) retaining spring, (8) brush block mounting plate.

Built-in versatility of this precision switch recommends it for a variety of uses, such as: indexed selector switch; sampling up to 10 circuits; pulse generation for precision measurements; telemetering applications; strain gauge and thermocouple switching; sequential scanning purposes; and numerous applications in aircraft, guided missiles, servomechanism, and computers. (Fig. 1)

The unit, Fig. 2, consists of 8 slip rings interconnected to an 8-segment commutator. 24K gold is used for the slip rings and commutator, while brushes are made of a special gold alloy in order to minimize contact resistance and maintain the lowest possible electrical noise level. Low starting torque (6 gram/cm max) selector switch is available with up to 10 positions in standard size 10 synchro housing. The regular dielectric material is suitable for ambient temperatures from −55°C to 100°C. Switches for higher temperature operation can be supplied on special order. (*From 4-page brochure, Electro Tec Corp., So. Hackensack, N. J.*)

FOR THIS LITERATURE CIRCLE 107 ON READER-SERVICE CARD

Electronic Circuitry

A continuing MILITARY SYSTEMS DESIGN feature, these circuits are selected because they represent good design. Significant characteristics which are not self-evident from the diagram are explained in the printed commentary.

Basic Zener Regulator

In its simplest form the zener diode regulator consists of a source of dc, a series resistor, and a shunt-connected diode as shown in Fig. 1.

The value of R_s is determined by the load requirements. If R_s is too large, the diode will be unable to regulate at large values of I_L. Conversely if R_s is too small the diode dissipation rating may be exceeded at low I_L values. The optimum value for R_s can be calculated from the equation;

$$R_s = \frac{V_{inmin} - V_z}{I_{Lmax} + 0.1I_{Lmax}}$$

where: V_{in} = supply voltage
V_z = zener voltage
I_L = load current

note: $0.1I_L$ is an empirical figure to insure diode regulation at high load currents.

When R_s is known, the maximum diode dissipation can be calculated by applying the following equation;

$$P_d = \frac{V_{inmax} - V_z}{R_s} - I_L V_z$$

where P_d = zener diode dissipation
R_s = series resistor in ohms

Series Transistor Regulator

Although the zener diode finds application in high current power supplies, its power handling ability is limited by the available dissipation. It would be quite impossible to use the circuit shown in Fig. 1 to control—say 1,000 watts—unless the diode was of rather immense proportions.

In these situations, it is customary to use a transistor (or group of transistors) as the series element in conjunction with a zener diode controlled reference. Such a circuit is shown in Fig. 2. The source, V_{in}, is applied to the zener diode through R_s and the base bias resistor R_B, establishing a reference base voltage with respect to the positive terminal. In effect the transistor functions as an emitter follower. Thus the emitter voltage is held within a few tenths of a volt of the base potential, which is determined by the zener diode.

The transistor acts as a series element to absorb voltage variations. Since the entire load flows through the transistor it must be able to dissipate the power absorbed by the junction. The power handling ability of the supply shown will be determined entirely by the number of transistors used and the ability to remove heat from the junction (s). Zener current is reduced to a small fraction of the original (Fig. 1) by employing the transistor.

Typical values for Fig. 2 might be R_s = 22 ohms, R_b = 1K, in conjunction with a 4.7 volt, ¼ watt zener diode. To check regulation a fixed load was attached to the output terminals and the input voltage varied between 0 and 30 volts. The resulting curve is shown in dashed line in Fig. 3. As a check of output regulation, the input was set at 16 volts and the value of I_L varied between 10 and 130 ma. The output regulation is shown by the solid line in Fig. 15.

To illustrate the improvement by using low dynamic resistance diodes, a 3.5 watt International Rectifier Corporation 3Z 4.7 diode was substituted for the ¼ watt unit. The increase in regulation was approximately 10:1.

This circuit can deliver a variable regulated output by installing a 1K potentiometer across the zener diode and connecting the movable arm to the base of the transistor. The regulation factor will be reduced slightly due to the shunting effect of the potentiometer.

Somewhat better regulation will be obtained if various zener diodes are switched into the circuit for different output voltages.

High Voltage Supply Zener-regulated

Although zener diodes are not usually associated with high voltage supplies (300 v.), they may be used in conjunction with transistors having a high E_{ce} breakdown.

Such a transistor is the 2N1136B, which has an E_{ce} of 80 volts and features 60 watts dissipation. This transistor is used as the series element in the negative lead of a high voltage regulated supply[1] (Fig. 4). The difference between input and output voltage is 80 volts with minimum load conditions. At the 200 ma maximum power supply rating, the transistor dissipates something less than 16 watts.

In operation, an increase in the load current causes a decrease in the bias on Q2 through the compound connected pair (Q3, Q4). The action of Q2, in turn, increases the bias on Q1, decreasing its resistance and thereby returning the output voltage to its nominal value. A decrease in load current reverses the action just described maintaining the output voltage at the correct value.

Source: "Zener Diode Handbook," International Rectifier Corporation, El Segundo, Calif.

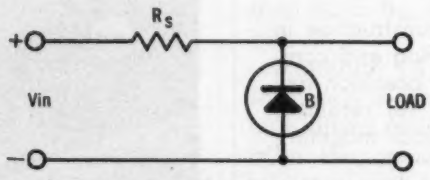


FIG. 1. BASIC ZENER diode regulator circuit.

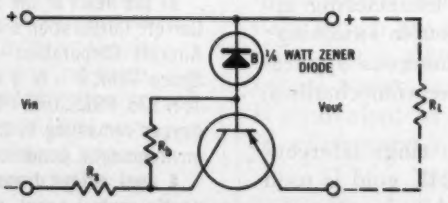


FIG. 2. ZENER-TRANSISTOR series regulator team is used to increase the current-handling capacity of the simple zener diode.

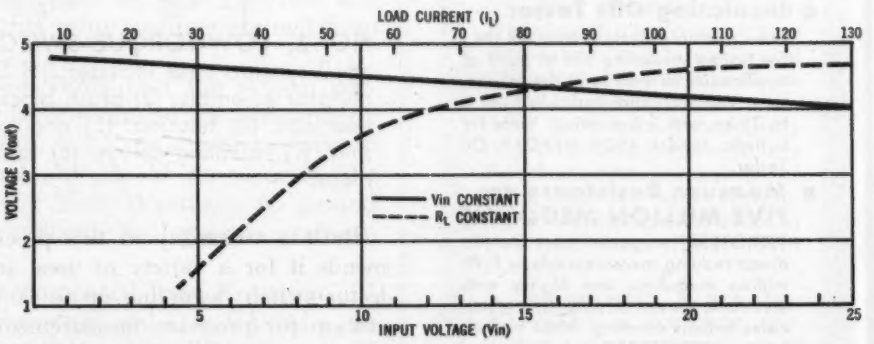


FIG. 3. REGULATION with changes in I_L and V_{in} for series regulator shown in Fig. 2

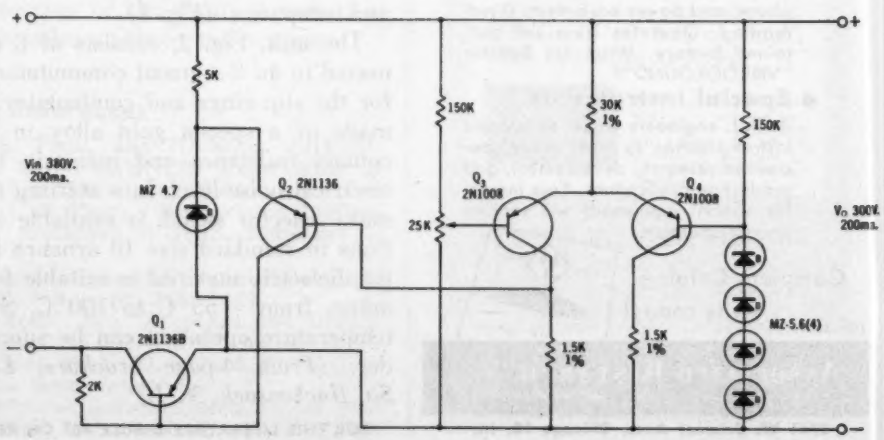


FIG. 4. HIGH VOLTAGE solid-state regulated supply for 300 v, 200 ma output.

[1]Courtesy Bendix Application Notes.

REVERSING DRIVE CONTROLLED BY SILICON CONTROLLED RECTIFIERS

A full wave reversing control or servo as shown in Fig. 7.13 can be designed around two SCR's with common cathode (SCR2, SCR3) and two SCR's with common anodes ((SCR1, SCR4). In this circuit, SCR2 and SCR3 are fired by the unijunction transistor, UJT Q1. Since SCR1 and SCR4 have electrically isolated cathodes, the gate signal pulse generated by UJT Q3 is coupled to the SCR gates by isolated secondary windings on transformer T1. Transistor clamp QS synchronizes the firing of Q3 to the anode voltages across and SCR4.

Potentiometer R1 can be used to regulate the polarity and the magnitude of output voltage across the load. With R1 at its center position, neither UJT fires and no output voltage appears across the load. As the arm of R1 is moved to the left, Q1 and its associated SCR's begin to fire, At the extreme left hand position of R1, full output voltage appears across the load. As the arm of R1 is moved to the right of center, similar action occurs except the polarity across the load is reversed.

If the load is a DC motor, plugging action occurs if R1 is reversed abruptly. R14 and R15 are used in series with each end of the transformer to limit fault current in the event a voltage transient should fire an add or even-numbered SCR pair simultaneously.

Input: 117v ac unregulated, —3v to —20v dc power for transistor.

Output: Dc power to drive load, 25 to 250v approx 10 amperes, as required by application and furnished by T_2.

Source: Circuit 7.9, "Controlled Rectifier Manual," Semiconductor products Dept., General Electric Co., Electronics Park, Syracuse, 1, N. Y.

POSITION SERVO USING SILICON CONTROLLED RECTIFIERS

Fig. 7.14 illustrates the use of SCR's in a relatively simple, yet highly reliable and compact position servo system. SCR1 and SCR2 deliver power to the respective fields in a split field generator or a pair of magnetic clutches. Which of the two fields is being excited at a given time depends in which direction the slave potentiometer is displaced from the position of the master potentiometer. By means of the free-wheeling rectifiers CR5 and CR6 across each of the fields, continuous DC current passes through each field when it is being excited.

Figure 7.15 illustrates voltage and current waveforms in this circuit. The first cycle represents the conditions when the arms of the master and slave potentiometers are in the same position. In this relative position, no AC voltage appears between the two arms and Q1 is biased by iB so that voltage V_C on the emitter of Q2 is slightly less than the necessary to fire this UJT. Neither SCR1 nor SCR2 conducts under these conditions. If the master arm is moved down to a new position, voltage V_E develops between the arms of the slave and master potentiometers as shown in the second cycle of Figure 7.15. The polarity of V_E is such that i_B is reduced while the anode of SCR1 is positive and increased when the anode of SCR2 is positive. Thus V_C increases and fires the UJT and SCR1 during the half cycle that the anode of SCR1 is positive. V_C decreases during the alternate half cycle, further preventing SCR2 from firing. The slave arm is mechanically coupled to the load so that as SCR1 fires and initiates movements in the mechanical system, the slave arm is moved down toward the position of the master arm. As it approaches the equilibrium position, V_E decreases and the firing angle increases to 180 degrees, at which point the system comes to rest.

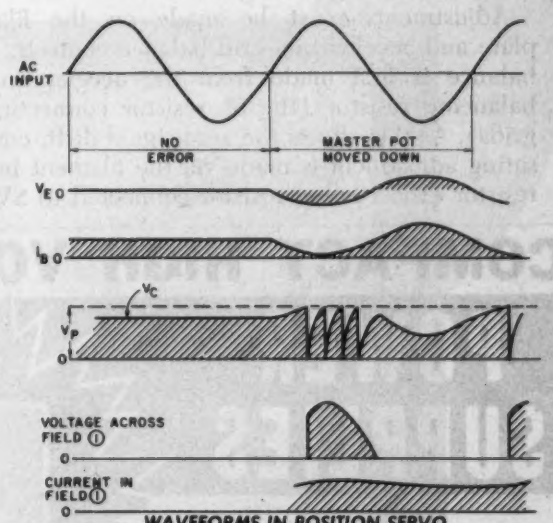
If the master arm is displaced upward, the system behaves similarly except that SCR2 and its associated field is excited instead of SCR1.

Input: 117 v ac 60 cps.

Output: Rectified and controlled dc current to either of two clutch or split generator fields, direct from 117v line.

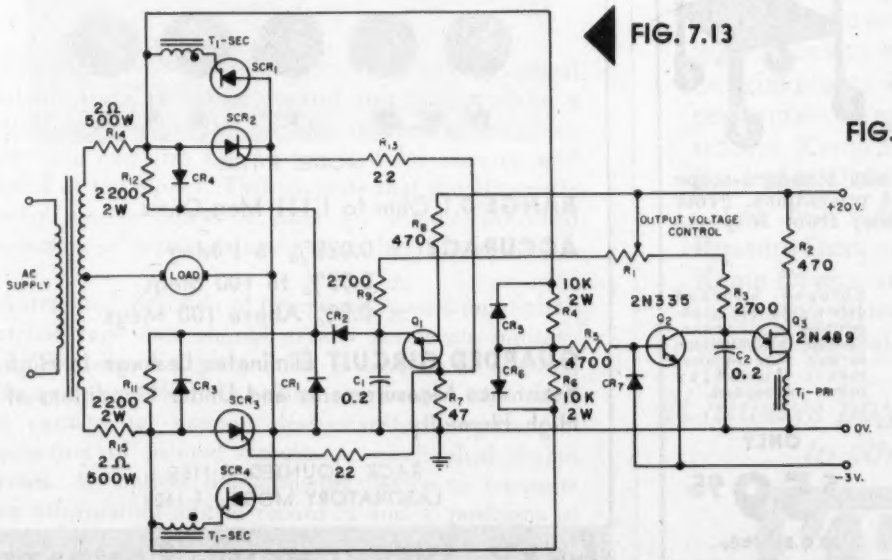
Source: Circuit 7.10, "Controlled Silicon Rectifier Manual," Semiconductor Products Div., General Electric Co., Electronics Park, Syracuse 1, N. Y.

FIG. 7.15. VOLTAGE and current waveform relationships in Circuit 7.10.



WAVEFORMS IN POSITION SERVO

FIG. 7.13

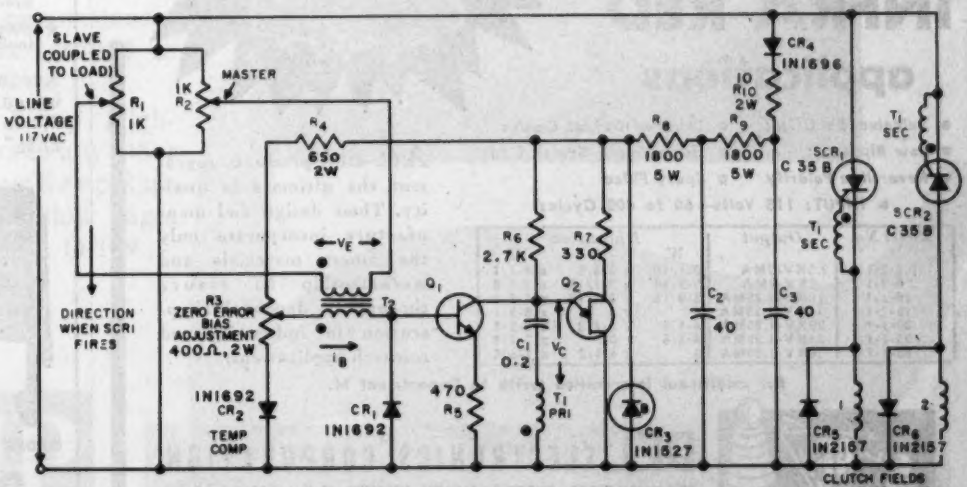


SCR_1, SCR_2, SCR_3, SCR_4 G-E C35 (VOLTAGE RATING DEPENDENT ON SECONDARY TRANSFORMER VOLTAGE)

CR_1, CR_2, CR_3, CR_4, CR_5, CR_6 — G-E IN196

T_1 — SPRAGUE 31Z382

FIG. 7.14



R_1, R_2 — 1000 OHM, 10TURN HELIPOT

CR_3 — IN1527 BREAKDOWN DIODE

T_1 — SPRAGUE 31Z382

T_2 — 110VOLT/0·6A TRANSFORMER

ELECTROMETER MEASURES CURRENTS OF 10^{-18} AMPERE

This balanced electrometer circuit is essentially a bridge. Electrometer tubes use low operating voltages, high vacuum, and low cathode-emission current to keep the grid current at 10^{-17} amp. The grid current includes not only electron and ion current, but also insulation leakage current and the current required to charge each capacitance from grid to ground, including probe capacitance. By proper balancing of the electrometer circuit (including plate resistance, accelerating grid potential and filament temperature), the circuit can be made insensitive to all factors other than desired signal current. Owing to the fact that the input probe is basically a capacitance that is being charged, the signal current can be calculated directly from the *rate of change* of the galvanometer current.

One problem is adjusting the zero-signal deflection rate. Grounding points are provided for both the inner and outer glass surfaces of the probe chambers, permitting surface charge to leak off without affecting the signal.

Adjustments must be made on the filament, plate and accelerating-grid balance controls. Major balance is first made from the accelerating-grid balancing resistor (the 5k resistor connecting the grids). As this affects the zero-signal drift, compensating adjustment is made via the filament balance resistor (the 10-ohm resistor connected to SW1.).

Victoreen Type 5800 electrometer tubes are used, and —1.5 v bias was used because the grid current does not change much with grid voltage at this bias and stability is improved. Grid bias is applied by closing switches 3A and 3B. These switches were operated by magnets because the entire probe and input system were in a vacuum.

An L&N Type R reflecting galvanometer was used as signal amplifier and detector. Sensitivity was 0.0027 μa per mm deflection at 1-meter scale-to-mirror spacing. Galvanometer period was 3 seconds; internal resistance 515 ohms; external critical damping 2200 ohms. (A chopper-stabilized d-c amplifier could be used instead of the galvanometer.)

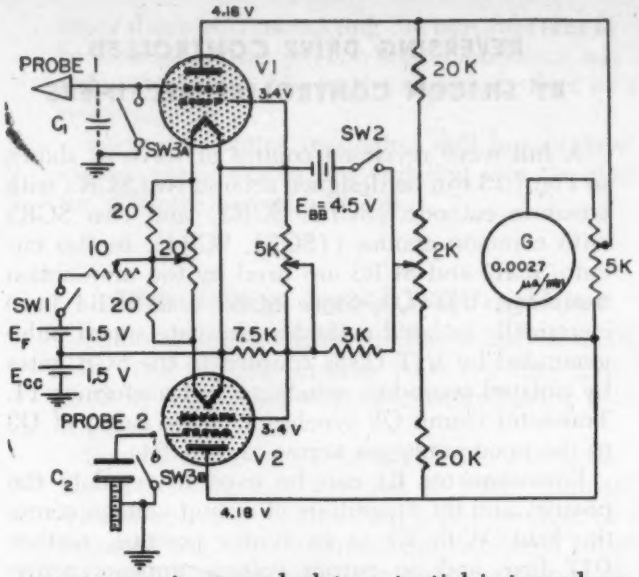
The input probe-to-ground capacitance was measured by bridge and found to be 4.5 $\mu\mu$f. The signal current was determined to be

$$i = (1.7 \times 10^{-15})\ (dx/dt),$$

where dx/dt is mm per second motion of galvanometer spot.

The zero-signal deflection was found to be 0.0263 mm/sec. When a molecular beam was directed at probe, deflection rate changed to 0.0417 mm/sec. Corresponding current was 26.2×10^{-18} amp, corresponding to (2.62×10^{-18}) times $(6.24 \times 10^{18}) = 163$ singly charged particles per second.

Balancing is time consuming, but electrometer will operate for months without rebalancing if filaments remain on and plate potential is turned on two hours before use.



Time to take a measurement varies inversely with the current. For currents of 10^{-17} to 10^{-18} amp, zero-signal rate was established in 600 seconds; additional 600 seconds established signal deflection rate.

B supply: 4.5 volt battery at 12 μa.

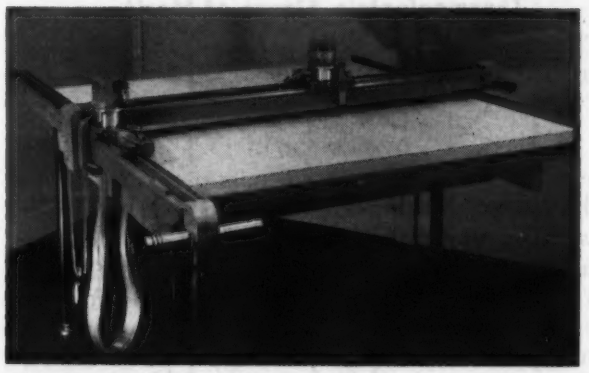
A supply: 1.5 volts at 10 ma.

Source: Robert L. Ramey and Robert L. Overstreet, U. of Va., Charlottsville, Va.; also "100 *Electronic Circuits*," Vol. 2, by Kezer and Aronson, Instruments Publishing Co., Pittsburgh 12, Pa.

Automated Layout Machine Plots Charts and Templates

A fully automated Aero/Haag-Streit Coordinatograph Plotter, for precise layout of grid systems and coordinate positions from punched tape or cards, is said to be applicable in precision layout of templates and charts, in aircraft and missile lofting to scribe grids directly on metal or other drafting materials, or to aid turbine blade design. The product of a two-year research and development program by the Aero Service Corporation and the Franklin Institute, both of Philadelphia, Pa., the automation provides a plotting accuracy of 0.0015″ over a working surface of 47¼″ x 47¼″. The manually operated Haag-Streit plotter is already in wide industrial use.

Maximum operating speed is 3 ips with the slowest speed 0.003 ips. Encoder resolution is to 0.001″ with a zero reference always retained by the instrument's static, directly-coupled system.



AUTOMATED Coordinatograph Plotter speeds precision layouts, can be operated by punched tape or cards.

The automated Coordinatograph includes a visual readout and Flexcounter control unit that provides a projection-type display of the digital information. Television can also be incorporated for viewing and control of the plotter. This suggests that the automatic control system could be used for remote-controlled machining of materials or in areas having radioactivity.

Automated direction of precision layout from digital-punched tape data should greatly accelerate military and other essential production in periods of national emergency as well as to reduce the amount of routine but painstaking manual draftsmanship required in production of printed circuits or mechanical design layouts. An optical line-following device to integrate area information and to record X and Y positions of irregular shapes will be produced as associated equipment with the Coordinatograph, according to design engineers of the Aero Service Corp., 210 E. Courtland St., Philadelphia 20, Pennsylvania.

FOR MORE INFORMATION CIRCLE 108 ON READER-SERVICE CARD

Thermoelectric Devices Now Competitive

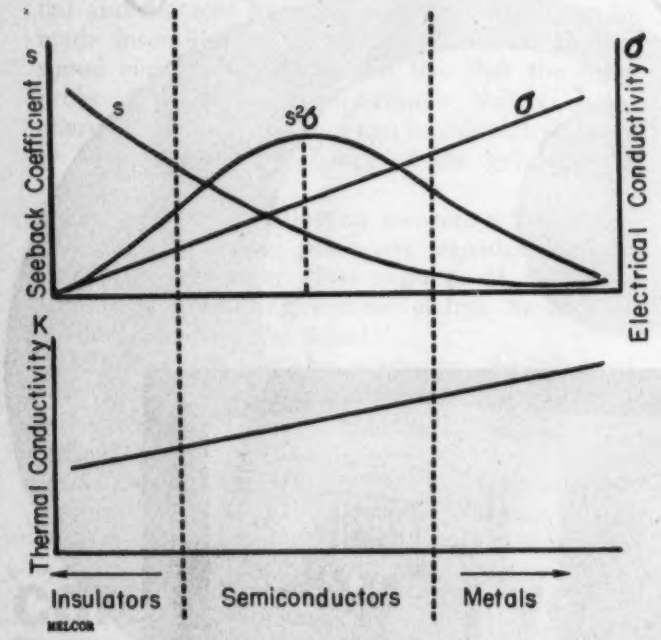


FIG. 1. THERMOELECTRIC capabilities of different classes of materials are illustrated by two graphs from which (relative conversion efficiency Z can be interpreted. The numerator of the expression $Z = a^2\sigma/k$ is given by the upper curve, labeled $a^2\sigma$. This must be divided by corresponding values for thermal conductivity, k, which generally increases from left to right, and is shown by the lower curve.

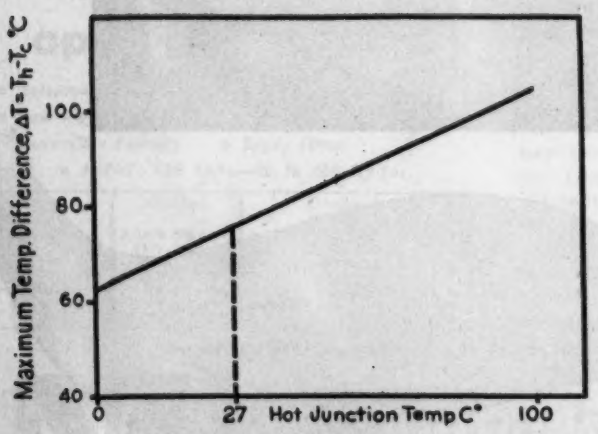


FIG. 2. MAXIMUM COOLING vs hot junction temperature relationship shows higher cooling efficiencies at elevated hot-junction temperature which is typical of all Melcor Module units.

SEMICONDUCTOR research in the last decade has at long last made practicable thermoelectric devices based on the Seebeck and Peltier effects discovered in the early 1800's. Although the Seebeck effect historically has had considerable application in thermocouples as a temperature measuring device, as long as energy conversion depended on the Seebeck effect between dissimilar metals, conversion efficiencies were too low to allow economic production of heat and cold by flow of current through a junction, or economical generation of electric power by direct application of heat to thermoelectric junctions.

Major recent advances in the development of semiconductors have created materials with high Seebeck coefficients, relatively low electrical resistivity for good conduction of electricity, and good thermal insulating properties. In contrast, although metals have good electrical conductivity, their thermal conductivities are also high, and much energy loss can be charged to the thermal "leakage" between the hot and cold junctions.

A wide variety of materials have been investigated for thermoelectric power applications. The types of system investigated have been tellurides, selenides, oxides, nitrides, carbides, arsenides and silicides of metals including the transition elements. Of all the materials investigated bismuth telluride and lead telluride type systems have given the highest efficiencies. Due to an emphasis on high temperature of operation in association with reactor heat sources (approx. 700°C) lead telluride is more widely used at the present time. Bismuth telluride type alloys, although operating temperatures are limited to 300-400°C, give efficiencies equal to or greater than lead telluride.

The debt that thermoelectrics owe to semiconductor technology is now being repaid by the impetus which small-volume cooling systems are giving to parametric amplifiers, masers, and infrared detectors; all semiconductor applications of military importance which perform best at low temperatures. The simplicity, light weight and reliability of thermoelectric cooling is another advantage in military systems, as is the case with which a cooling system can be converted into a heating system by a simple reversal of the current direction. Manned space craft, in which moderate temperatures must be maintained in ambients alternating between extreme heat and cold, may use these devices.

Another military application which is ripe for immediate use is the airconditioning of nuclear submarines, which range from tropical to arctic waters and in which quiet operation, economy of space and reliability is essential. Other military uses of thermoelectric power generators are suggested by the complete quiet with which they operate, and by the ease with which they can be teamed with solid-state converters to change a comparatively low-voltage, high current dc output into any voltage or frequency which may be demanded by the application.

Thermoelectric Figure-of-Merit

The figure of merit of a thermoelectric device is expressed by the formula:

$$Z = s^2/\rho k \quad (1)$$

$$\text{or } Z = s^2\sigma/k \quad (2)$$

where Z is figure of merit in units per °C, s is the Seebeck coefficient (MV/°C), ρ equals electrical resistivity (ohm-cm), and k is thermal conductivity (watts/cm/°C). In the second form of the equation σ (electrical conductivity) is substituted for $1/\rho$. The relative efficiencies which can be expected of insulators, semiconductors and metals is shown in Fig. 1. Although insulators have high Seebeck coefficients, their low electrical conductivities make the figure of merit low at normal temperatures. Metals similarly suffer from a low Seebeck coefficient and low thermal conductivity. The class of semiconductors, however, promise, through an optimum balancing of all factors, effective figures of merit.

The ideal material for most thermoelectrics applications should operate efficiently for cooling, as well as for the generation of power. To date, bismuth telluride and its alloys are the best materials that have been developed for cooling applications. Figures of merit of 3- to 4 x 10^{-3} have been realized. This compares with a figure of merit of 1.5 x 10^{-3} for lead telluride and of 1 x 10^{-4} for most other systems. In a cooling system, a figure of merit of 3 x 10^{-3} will cool 75°C below an ambient temperature of 27°C (300°K).

Measurement of Thermoelectric Characteristics

For power applications in which generation of power from a temperature differential is maintained by the application of energy on one end of the thermopile while the other end is applied to a heat sink, the familiar equation, $\text{Eff} = P_{out}/P_{in}$ is

applied. In a number of applications, however, the simplicity of thermoelectric generators may make practical the reclamation of power for battery charging from the heat of exhaust engine gases, now wasted; thus saving much of the considerable engine horsepower now used in driving automobile generators.

In cooling applications several parameters are important, but the basic one is the figure of merit. The higher the figure of merit, the greater the temperature difference below an ambient temperature that can be attained with a single stage cooler. In applications where lower temperatures are needed, multistage coolers can attain lower temperatures by the inner stage exhausting into a heat sink which is pumped out by a second thermoelectric pile, and so on. At lower ambients, however the efficiency of the cooling effect falls off so that not more than three stages are considered practical. The effect of lower and high ambient temperatures on the efficiency of a Melcor BiTe alloy is shown in Fig. 2. Higher hot-junction temperatures result in more cooling from a typical Melcor module than at lower hot-junction levels.

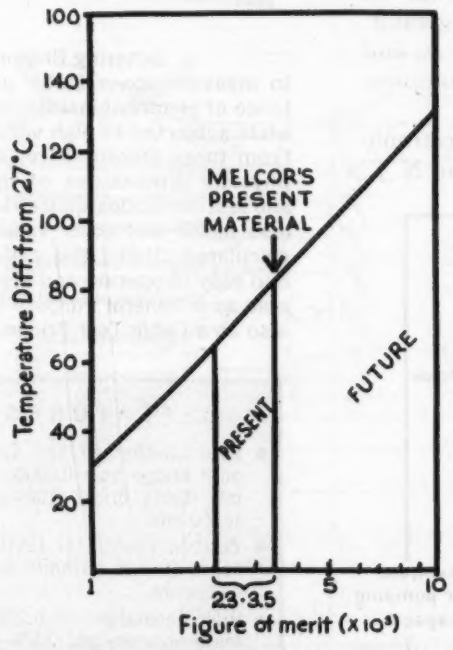


FIG. 3. FIGURE OF MERIT has all-important effect on feasibility of thermoelectric cooling. Average value of 3.5 for Z enables competition with compressor-type cooling in household-size refrigerators, is superior in small-size, military applications such as IR detectors, parametric amplifiers and masers.

The effect of figure of merit on cooling differentials is illustrated by Fig. 3, in which figures of merit from 2.3 to 3.5 represent the range of semiconductor thermoelectrical materials available today. Melcor's Bi Te alloys, which provide a figure of 3 x 10^{-3} for N materials and a figure of 4 x 10^{-3} for P materials, are in the upper region of this range. In these measurements, all are made in a vacuum so that no convection losses are present.

Variations in the heat-pumping capacity of any particular module when different amounts of cur-

rent are applied is another important factor in the design of thermoelectric cooling devices. The cooling capacity of Melcor modules in the MC 7 series is shown in Fig. 4, which shows that for any given current input, the pumping capacity in watts per couple is inversely proportional to the temperature differential.

Thermoelectric Material Costs

The cost of thermoelectric materials to date has been expensive as is usually the case in the experimental and developmental stages of a novel principle. Sample orders come high, with a single thermoelectric couple with both N and P type materials selling for approximately $1 a gram or $500-lb. The basic material has been sold by some companies at approximately $1500/lb!

In comparison with such prices, producers of commercial refrigeration units who place production orders with Melcor can now buy thermoelectrics in finished fabricated form for as little as $75/lb. Since only one-half pound or less would be needed in a small-volume (3-4 cu-ft) refrigerator, thermoelectrics are obviously as economical as, and are now in direct competition with, motor-compressor refrigeration units.

In fact, the formation of the Materials Electronic Products Corporation, (MELCOR), Trenton, N. J.,

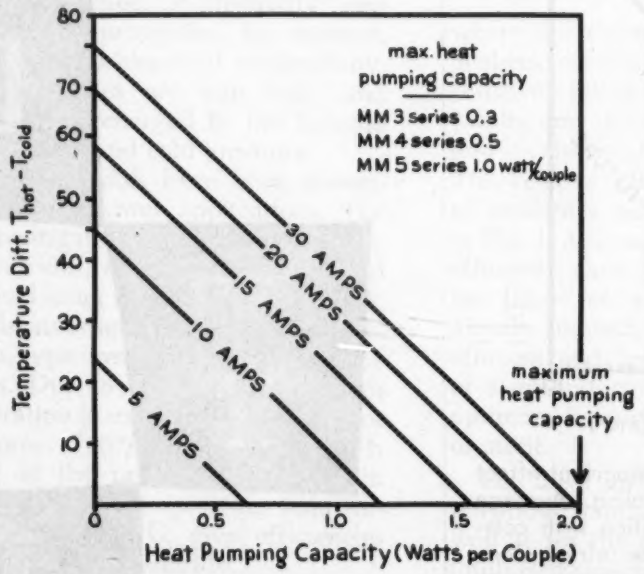


FIG. 4. HEAT PUMPING capacity of Melcor MC 7 when different amounts of current are applied. Effect of different hot-temperature junctions is also shown.

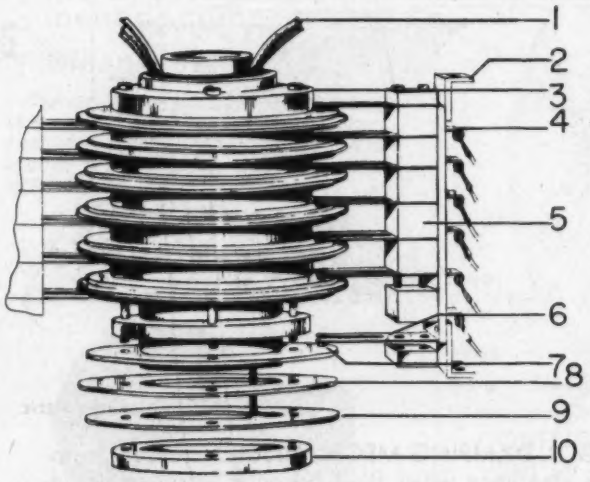
by five scientists all formerly of the RCA David Sarnoff Research Center, Princeton, N. J. is at the same time evidence of, and a factor in the growing potentialty of thermoelectrics. Organized in October 1959, in six months Melcor has developed a thermoelectric material with a figure of merit between 3 and 4 x 10^{-3} selling at a cost that makes it competitive for refrigeration. They also have introduced the first commercially available complete line of finished thermoelectric module units in sample and production quantities.

Three Types of Slip Ring Assemblies

A typical flat ring assembly (Fig. 1) consists of slip rings (A), flat discs made from silver alloys. Rings are mounted in pairs, above and below insulating barriers (B) which are, in turn, separated by insulating spacers (C). These components are bolted to a mounting flange (D). Lead wires (E) are attached to the slip rings.

Making contact with each ring is a brush (F) made of silver graphite which, in combination with the silver alloy ring, provides the desired electrical conductivity, low contact resistance and low wear rate. Brushes are welded to beryllium copper springs (G) assembled with insulating spacers (H) and terminals (I) and bolted together between mounting brackets (J).

Cylindrical assembly: In this type of assembly the rings run vertically around a shaft and the brush contact is made on the vertical rather than the horizontal plane.



FLAT RING type Slip Ring Assembly. Lettered parts are named in text.

Concentric Assembly. This assembly consists of rings having various diameters mounted concentrically on a flat insulating support plate. The concentric assembly can be made in multiples and stacked vertically with space between the sections for the brushes.

Slip ring assemblies can handle many type of circuits ranging from microvolts to over 30 kilovolts, currents from microamps to amperages above 1000 amperes and frequencies from c.c. to 1000 megacycles. The rings can be segmented to permit switching and thus perform programming and telemetering functions.

Slip ring circuits are comparable to continuous wires or cables in several respects. Crosstalk between circuits is similar to that experienced with shielded cable. Contact and bush resistance is lower than the resistance of wire leads and under operating conditions noise is a function of current and generally is negligible. (*From 24-page catalog 66SR "Standard and Custom Slip Ring Assembles", Breeze Corporation, Inc., 700 Liberty Ave., Union, N. J.*)

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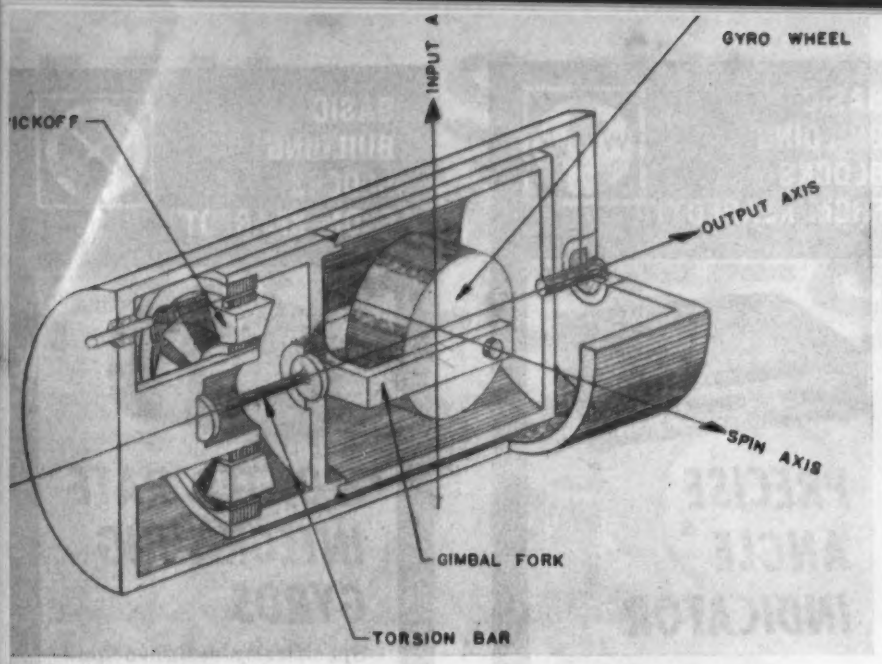

FIG. 1. RATE GYRO responds to rotation about input axis by precessing about output axis, resulting in torque which is proportional to rate of angular acceleration.

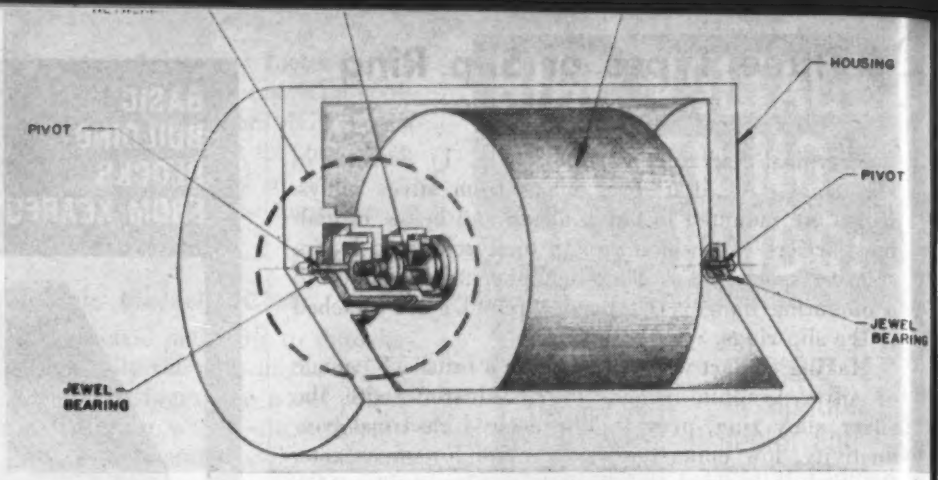

FIG. 2. JEWELLED BEARINGS and spider remove support tensions from torsion bar, which acts as restraining spring on precessing torque.

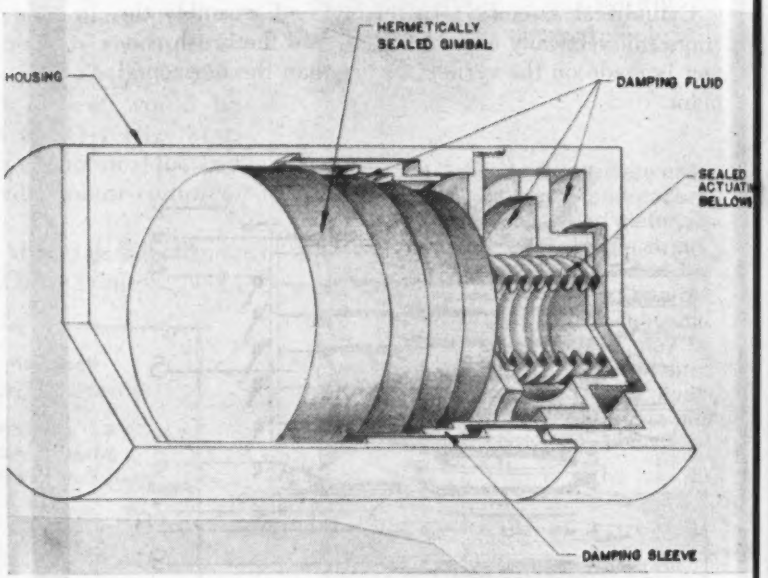

FIG. 3. DAMPING MECHANISM decreases damping clearance when fluid becomes less viscous, increases clearance as fluid becomes more viscous.

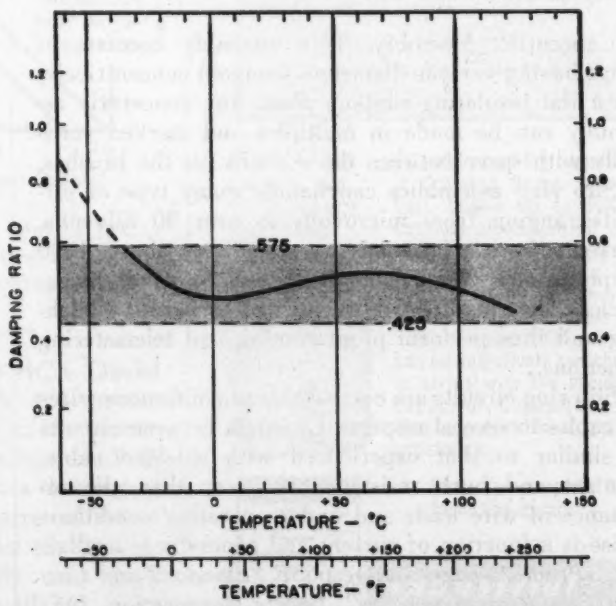

FIG. 4. TYPICAL DAMPING curve for Fairchild RG-100 Rate Gyro.

A New Subminiature Rate Gyro

Today's gyroscope, as a basic sensor of angular position, has been improved to such an extent that it can furnish fast and accurate information far beyond human capabilities. Gyroscopes, including rate gyros which detect angular rates by measuring the torque produced, have evolved from the once brute force device to the precise position control subsystems now used in missiles and high-performance aircraft.

The Fairchild RG-100 Rate Gyro continues this trend in the subminiature gyro field by improving in some areas, and maintaining in other areas, the high degree of precision now expected of gyros. The RG-100 has additional features, such as external adjusting ports which enable precise gimbal balance after assembly, a controlled damping mechanism which affords uniform controlled damping over a wide temperature range without heaters, and pivots with jewelled bearings supporting the gimbal at both ends to relieve the torsion bar of supporting strains. Due principally to the use of these pivots, the RG-100 is capable of withstanding 100 G shocks and 15 G to 2000 cps minimum vibration on any axis at rates even lower than 20°/sec. (Fig. 1).

Rate gyros consist of three basic elements: 1) A spinning gyro wheel contained in a gimbal which supplies the necessary angular momentum. The gimbal has a single degree of freedom. 2) A spring (torsion bar) which restrains the gyro gimbal thus allowing a measurement of rates of turn. 3) A pickoff which produces a signal in volts proportional to the angular rate of turn.

The motor driven gyro wheel supported in the gimbal fork, when excited with 400 cps, revolves at 24,000 rpm thus supplying the necessary angular momentum and establishing an inertial position. An input angular rate exerted along the input axis will set up a torque in the torsion bar which is restraining the gimbal fork. This torque will tend to rotate the pick-off rotor and emit a signal in volts which is proportional to the torque and calibrated to input rates.

The unique supporting structure of the RG-100 (Fig. 2) is provided by the pivots and jewel bearings at both ends of the gimbal in line with the torsion bar. The bearings support the gimbal assembly through the spider network, relieving the torsion bar of any duty other than its action as an axial restraining spring.

Another outstanding feature of the RG-100 is the damping mechanism (Fig. 3) utilizing the silicon fluid damping medium as a temperature sensing device. As the temperature rises, the fluid becomes both less viscous and increases in volume. The increase in volume compresses the sealed actuating bellows causing the shear damping area between the damping sleeve and gimbal to be increased. This process is reversed as the temperature decreases. The damping area is varied by means of the step construction between the gimbal and damping sleeve so as to insure a linear or uniform controlled damping throughout the wide temperature range from —40°F to 200°F (Fig. 4).

Other specifications of the RG-100 gyro, 15/16" diameter by 2" long, are: Maximum input rates from ±20°/sec to ±800°/sec; input power approx 3 watts @6.3v or 26v, 400 cps; output signal delivers a signal of 6v at 400 cps which is phase sensitive; linearity is 0.1% of full scale to half scale, 3.5% of full scale to full scale; hysteresis is only 0.15% of full scale and gimbal balance in standard models is as low as 0.1% of full scale per G. Balance can be as low as 0.02% of full scale per G on special order. (*From new 16-page technical bulletin Model RG-100 Subminiature Floated Rate Gyro, Fairchild Controls Corporation Components Div., 225 Park Ave., Hicksville, L. I., N. Y.*)

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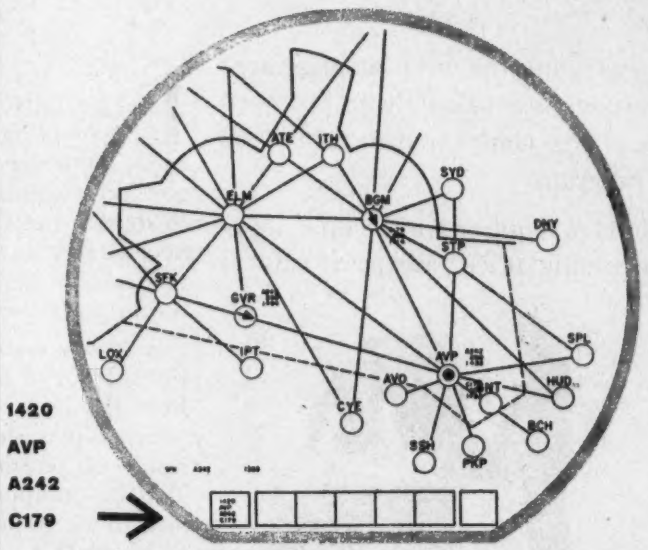
Computer to Automate Air Control

A contract for a new computer, designed specifically for air traffic control of civil and military air traffic under the Federal Aviation Agency control facilities, has been awarded to the GPL Division of General Precision, Inc., Pleasantville, N. Y. Designed to expedite coordination between controllers now operating among the nation's 33 air traffic control centers, computations from data entered manually or automatically will be processed and information presented to appropriate controllers through an array of display consoles. In the event of anticipated conflicts, where two aircraft are on courses that would bring them too close to each other for safety, air traffic controllers will be alerted as much as 30 minutes in advance (See Figure).



CONFLICT DISPLAY, one of the new tools provided air space controllers by the new system, is illustrated in system display. After warning lights signal a conflict, controller presses button which directs computer to provide data, showing conflict at AVP between flights A242 and C179.

Because the new system is designed to augment present control methods which use chiefly manual methods of computation, the progress through semi-automatic to almost fully automatic operation is expected to be smooth, and to allow resumption of manual control during emergencies should breakdown of any part of the automatic system occur. Scheduled to be in experimental operation at the FAA National Aviation Facilities Experimental Center at Atlantic City, N. J., it is expected that similar data processing systems will be installed eventually on a nationwide basis. (*From 10-page bulletin, "Breaking the Air Traffic Jam," General Precision Equipment Corp., 92 Gold St., New York 38, N. Y.*)

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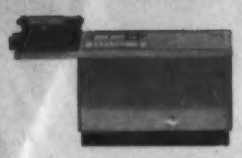


LGP-30 COMPUTER ABSTRACTS

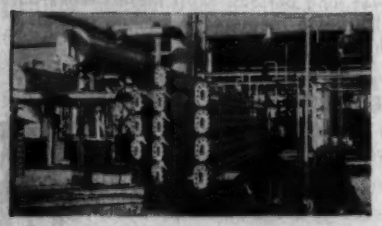
(Application Report #10, from which the following is abstracted, is free upon request from Royal McBee Corporation, Data Processing Division, Port Chester, N. Y.)

Subject: Design / User: Brown Fintube Company, Elyria, Ohio

THE PROBLEM: rush quotation for heat exchanger to potential customer. Determine best heat exchanger vs. cost combination. Perform necessary computations to obtain values for total surface area; total number of exchangers; area/exchanger; velocity and pressure drop—shell and tube; film coefficient; log mean temperature difference; overall transfer rate; clean rate; overall fouled rate; surface actually required; duty; price.

METHOD: the compact, low-cost Royal Precision LGP-30 Electronic Computer.

INPUT DATA: except for special specifications which are handled by design engineers, non-technical personnel fill in data directly from customer inquiry sheets. This information is then punched on tape.



SOLUTION: the engineer reads the above data into storage in specifically assigned memory locations on the computer's magnetic drum. The set of program instructions—also stored on the drum—then directs the computer where to find the input data and what mathematical operations to perform in the proper sequential order. The program then further directs the computer to store the various answers in specifically assigned memory locations.

Of notable interest is the incorporated test feature which allows any type and arrangement of sections to be tested by the computer. The program not only compares calculated values, but provides a corrective computation and recomputes all conditions until satisfactory values are obtained. The engineer need only type in the exact arrangement desired to have the computer calculate his proposed arrangement – assuring complete versatility and control over the program.

OUTPUT: all numbers required for the final specification sheet, including price, are provided – as well as key intermediate answers to enable the engineer to exercise judgment. The computer automatically controls the typewriter so that all answers are printed out in the desired format.

CONCLUSIONS: with the LGP-30, Brown Fintube has reduced total time on typical heat exchanger designs from one or two hours to approximately 3 minutes. Better design vs. cost combinations have been obtained—with a resulting increase in contract awards and the elimination of under-bidding. According to company officials, "perhaps the most significant contribution of the LGP-30 has been the release of engineering manpower for more basic and profound studies."

Royal Precision Corporation

Royal Precision is jointly owned by the Royal McBee and General Precision Equipment Corporations. LGP-30 sales and service are available coast-to-coast, in Canada and abroad through Royal McBee Data Processing offices. For your free copy of Application Report #10, as well as full specifications on the compact, mobile LGP-30, write today to **ROYAL McBEE CORPORATION,** data processing division, Port Chester, N.Y

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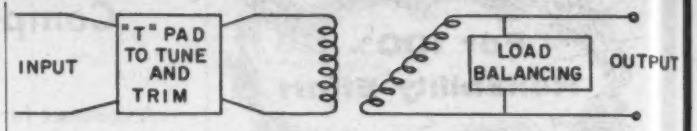

FIG. 1. TUNED and trimmed resolver stage eliminates complex impedance loading, effects, minimizes losses and phase shift.

Resolver Chain

ELECTRICAL RESOLVERS, used as analog computing elements, can be applied in cascade by using one of the two techniques. One method, frequently used, requires buffer amplifiers to standardize resolver output and phase shift, and necessitates an additional winding in the resolver to provide the feedback voltage required by the buffer amplifier.

A second system, which requires no amplifiers, is the subject of this discussion. The system benefits from the higher innate reliability that fewer components provide, uses only high-quality standard resolvers, requiring no special feedback winding. The design approach is to build the resolvers with near-unity transformation ratios, low phase shift, and high Q. Close manufacturing tolerances should be maintained to ensure that each resolver is nearly identical to all others. Starting from this basic unit the amplifier-less resolver computing chain may be developed.

When a number of standard resolvers are connected in cascade, there will be considerable loss in signal to noise ratio and a large buildup of phase shift as the input voltage is operated on by each resolver in the chain. The transformation ratio of the individual resolvers is not the same due to loading effects. That is, each resolver presents a fairly low impedance load to the previous resolver and, in turn, is similarly loaded by the next unit in the signal path. This means that each successive resolver will exhibit a lower transformation ratio than the one before it. In addition, the phase shift of each resolver will be increased by the complex impedance loading effects. Total phase shift will be the sum of all shifts in the signal path. This obviously is not a desirable system for any use.

An efficient computing chain may be obtained by tuning and trimming each resolver so that the input and output impedances appear purely resistive. Phase shift of the unit has been eliminated. By tuning and trimming the resultant transformation ratio is slightly less than that of the untrimmed re-

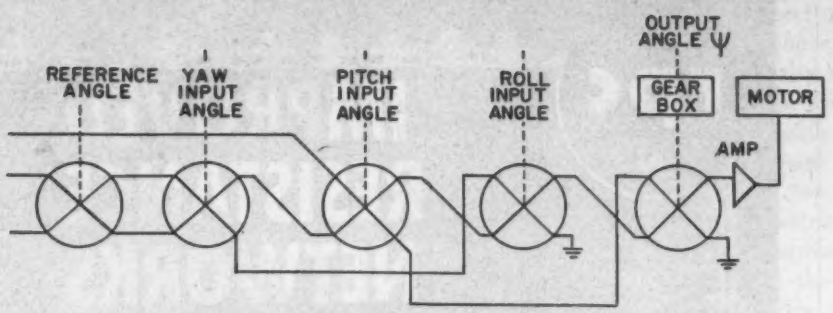

FIG. 2. TYPICAL resolver computing chain composed of resolvers with iterative tuning.

Without Amplifiers

PHILIP THIER
Sr. Project Engineer
American Electronics, Inc.
Culver City, Calif.

solver but, as will be shown, this does not detract from the merit of this approach (Fig. 1).

Having identical input and output impedances and making all resolvers in the chain identical to each other, the system, known as iterative tuning, provides complete interchangeability of parts and vastly improves the performance over that of the untuned system.

Consider, now, the loss of signal through a computing path. Without tuning, the losses are prohibitive. For the tuned chain the transformation ratio of each unit is not affected by the preceding or succeeding units. The resultant transformation ratio of a signal path is the transformation ratio of one resolver raised to a power equal to the number of resolvers in the path. This will always be greater than the output obtainable with untuned resolvers. Since the phase shift of each resolver is zero, then the total phase shift of the chain is also zero.

Optimum resolver performance requires that both outputs be equally loaded. At times the computer design, by itself, cannot provide balanced loads. This may come about if only one output is required from a resolver or one output feeds an amplifier while the other feeds into the next resolver. In such cases a compensator is normally a single stator, single rotor device, tuned and trimmed to simulate one phase of one of the true resolvers in the chain. The rotor is locked at the maximum coupling position.

For those instances in computing chain design where it is necessary to add two signals a two-phase resolver-compensator may be used. The summing compensator is a normal two-phase resolver tuned and trimmed to be identical to the other units. However, this unit will have the rotor locked at the maximum coupling position and the two rotor windings connected in series adding. The summing compensator acts like a differential transformer so that the rotor output voltage is the algebraic sum of the two stator input voltages modified by the unit transformation ratio.

Microcircuit Reliability is Design Goal

Emphasis is placed on reliability as the prime single factor in the development of microcircuit techniques by the research division of the International Resistance Co., Philadelphia, Pa. Dr. John J. Bohrer, Director of Research, has stated, "It is obvious that a great deal of reliability data must be collected in advance of military acceptance, and the techniques of microcircuitry and molecular electronics should lead to more reliable functioning than is available with most existing circuitry and components."

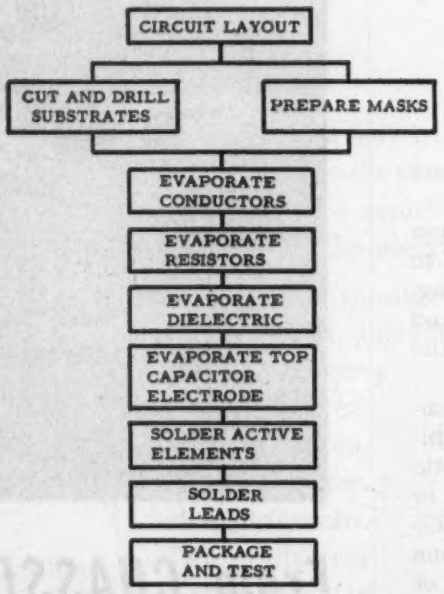

FIG. 1. MU-CIRCUIT FLOW CHART shows sequence of operations presently used in fabrication of the new microcircuits.

Production of a new thin film "Mu Circuit" is being coordinated with exhaustive testing and evaluation both of its performance in normal use, and in its ability to withstand environmental conditions. The "Mu-Circuit" is a product of the operations shown sequentially in the flow chart of Fig. 1. In this process, the passive elements are deposited by vacuum deposition techniques upon a thin glass or ceramic substrate which has been drilled to receive such separate active components as are necessary. Eventually, the fabrication of active elements is expected to be incorporated into the deposition sequence.

Design of the Mu-circuit rests on a series of developmental tests in which the area, geometry and resistivities are optimally related to resistor comformation, and similar factors of deposited circuit design for other components, are determined. Next, substrates are prepared and evaporation masks fabricated. The conductive pattern, bottom capacitor electrode and terminations are then vacuum-deposited on the substrate surface through the appropriate mask. Again using an appropriate mask, the resistors are applied

to the circuits so that they connect the conductive pattern at appropriate points on the circuit. The resistance values are established by the resistivity- per-unit-area of the resistive film and the pattern geometry. This step is followed by the deposition of a dielectric film by evaporation or sputtering over the previously deposited bottom electrode. The top electrode for capacitors is then evaporated so that it connects with the conductive pattern at the appropriate points (Fig. 2). The thickness of the dielectric, the dielectric constant, and the area of the electrodes are all used to

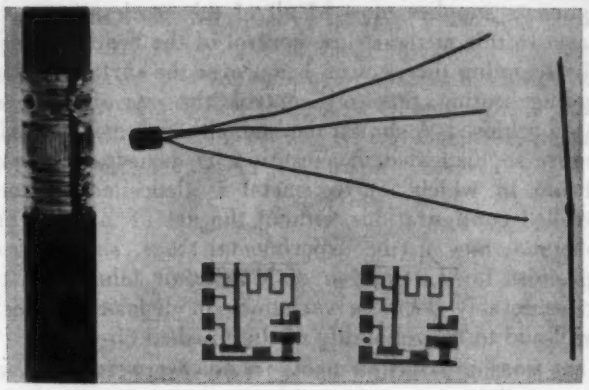

FIG. 2. COMPLETED WAFER in Mu-Circuit construction shows passive elements formed and ready for insertion of active elements, also transistor and diode before attachment.

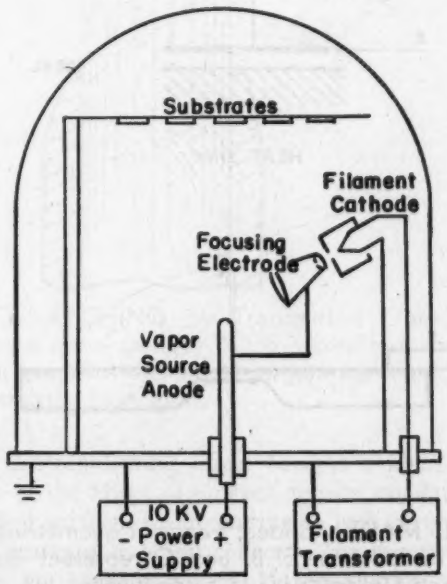

FIG. 3. ELECTRON GUN method of thin film deposition provides control of deposition rate by scanning of electron beam.

control capacitance. Miniature diodes and transistors are then soldered into place, and if it is desired, leads for input, output and bias connections are attached. The circuit is now ready for testing.

Mu-circuit "components" have received exhaustive testing in still air on life, temperature coefficient, noise and resistance to environmental stresses, and

have been found to meet appropriate Mil-spec requirements. Tolerances values of ±5% are achieved by the techniques of vapor deposition.

The process of evaporation and deposition of materials is accomplished in a vacuum chamber by one of many possible methods. Originally, resistance heating of a crucible or boat in which the evaporant was placed, allowed the vapor to be liberated in the vacuum for deposition on the masked substrate. Because of tendencies of evaporants to react with boat materials to produce contamination, electron bombardment heating is now being used. In one type, the self-accelerating electron beam system, (Fig.) one of the gun components supplies most of all of the accelerating voltage. In this method close control of the heating effect, by scanning the electron beam over the surface undergoing heating, precisely controls the rate of evaporation achieved. A similar method, although considerably more sophisticated in execution, is deposition by ion beam in which ionized metal is deposited in controlled configurations without the use of masks. This method, now in the experimental stage, shows great promise for automation of Mu-Circuit fabrication to considerably decrease variations in deposition which will add to the reliability of the finished circuit.

High-Power Transistors by New Etch Process

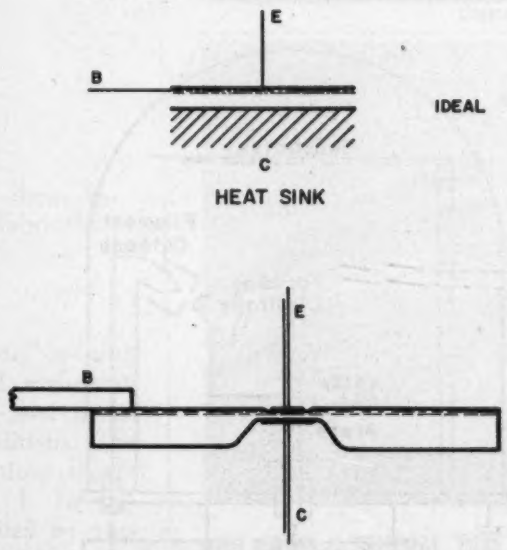

FIG. 1. MADT and Ideal transistor geometries show close comparison. E, B, and C represent Emitter, Base and Collector leads, respectively.

Etching by transmitted light, a process recently announced by Dr. C. G. Thornton, Director of Semiconductor Research and Development for the Lansdale Div., Philco Corporation, is credited with making possible high power Micro Alloy Diffused-base Transistors (MADT) which are inherently close to ideal design for high frequency applications.

The MADT technique has long been recognized to offer superior high frequency characteristics due to the extreme thinness of the diffused base layer per-

mitting short carrier transit time, high frequency response, and optimum switching performance. A heat sink is located close to the collector-base interface to remove heat quickly, and emitter and collector electrodes are kept no larger than necessary for the desired current levels. A diagram of the conventional MADT shown in Fig. 1 shows that this design closely approximates this ideal. However, the problem of achieving a sufficiently large, thin and flat base-collector interface has heretofore prevented the application of MADT design to high-power units.

Precision etching is somewhat analagous to diffusion techniques, in that it also controls basewidths. Unlike the diffusion process, however, precision etching is relatively immune to local variations and imperfections in the semiconductor material. Philco research has established that high etching speeds and uniform illumination of the semiconductor material are two vital factors in the etching process.

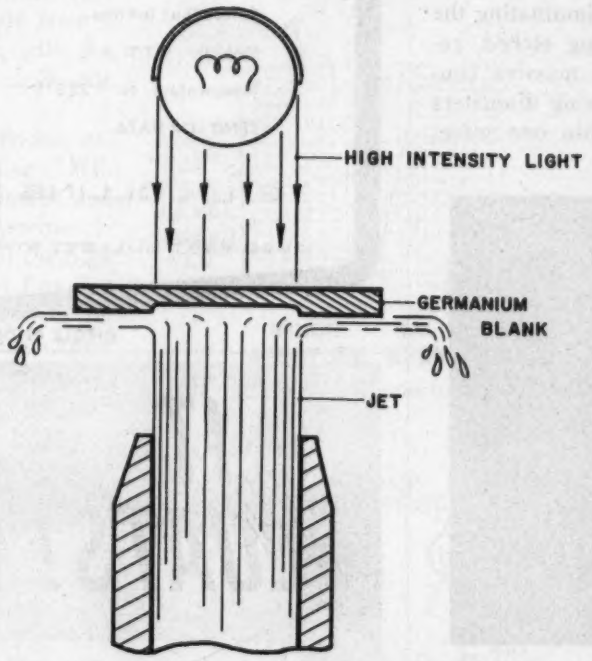

FIG. 2. ETCHING by Transmitted Light (ETL) technique developed by Philco is credited with success in precision etching of large-area, high-capacity transistor base area.

The electropolishing effect became evident during a study of the effect of current density on flatness of the etched surface. In attempting to etch at very high speeds, germanium atoms collect in any minute valleys and are not easily removed. Moreover fresh solution cannot enter the valleys readily, therefore etching is impeded in these sites. Conversely etching is very rapid at the peaks, where there is always a fresh supply of solution. The net result is that an almost perfectly flat surface results. Interferograms of material subjected to this electropolishing process show that such surfaces are flat to better than one wavelength of sodium light.

The importance of illumination during etching has been recognized in conventional etching techniques. The surface of a wafer of germanium is composed of hydrated germanium atoms tightly bonded by electron

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pairs to germanium atoms deeper in the crystal. In order to remove germanium atoms at the surface, holes must be brought in to replace the bonding electrons, permitting the surface atoms to dissolve in the jetstream. Light energy (photons) impinging on a germanium atom in the semiconductor wafer, creates hole-electron pairs. The electrons thus created move off to the external circuit, while the holes drift to the circuit being etched. Four such holes replace the electrons which bond the hydrated germanium atoms to the surface, and the atoms dissolve in the jetstream.

Standard precision etching methods, in which the wafer is illuminated from the side of the jetstream, resulted in convex pit bottoms in etched pits larger than 12 mils in diameter. This was caused by the fact that holes tend to recombine while travelling through the material, making more holes available at the edge of the pit than the center, thereby making the center of the pit higher than the edges.

The Etching by Transmitted Light (ETL) technique developed by Philco consists in illuminating the wafer from the side opposite that being etched, resulting in the generation of an even, massive concentration of holes. As a result, pits having diameters greater than 115 mills are flat to within one wavelength of sodium light.

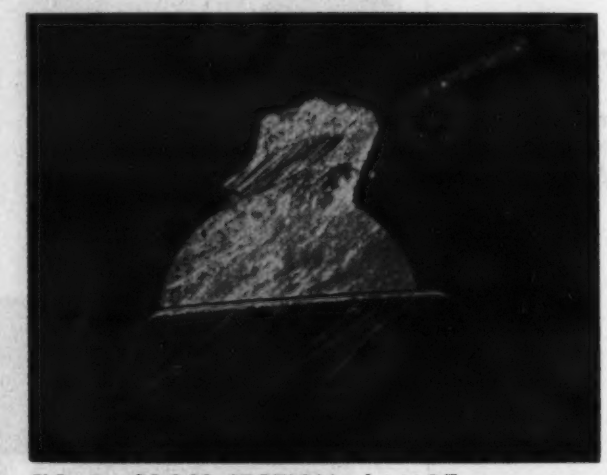

FIG. 3. CROSS SECTION of MADT power transistor with gain bandwidth of 33 mc.

Using the ETL process a 15 watt MADT has been developed (Fig. 3). In contrast to other high power devices it shows a high degree of radiation resistance, and is being evaluated under a Signal Corps contract for use in a dc-ac converter for a nuclear radiation environment. High-power high-frequency switching MADT's have demonstrated remarkably low switching times. Saturated rise, fall and storage times are typically 40, 75, and 35 μsec, respectively, at a collector current of 1 ampere. The narrow collector region assures high efficiency operation; collector resistance is approximately 0.4 ohm ($I_c = 1$ amp, $I_b = 0.1$ amp.). Gain bandwidth at an emitter current of 150 ma is typically 33 mc, about three times larger than the best diffused-base unit now available. Beta linearity is quite good.

The ETL technique is also expected to have application in the fabrication of solid-state circuits now being designed.

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Multiaperature Devices

AMP-MAD*, a multiaperture memory device, employing specially-shaped, magnetic cores in which a number of minor apertures are spaced about a major aperture (Fig. 3), can provide storage of digital and analog data. Using square hysteresis loop ferrite materials, these new gometric configurations uniquely provide intrinsic non-destructive readout of stored data. The new principle is a development of the Syscom Division, AMP Incorporated, Harrisburg, Pa.

In digital applications, the intrinsic non-destructive readout capabilities of MAD eliminate the need for rewrite programming and circuits where repetitive readout is required. In buffer applications, the many minor apertures permit multiple, independent, non-destructive outputs from each MAD core. This means that information can be transferred simultaneously from a central data source to a number of inputs, with the readout rate from the MAD adjusted to the clock rate of each input.

Sufficient voltage and power, without diodes, capacitors or transistors, can be controlled from AMP-MAD shift registers to drive incandescent lamps and other indicating devices in visual display systems.

In analog applications, taking advantage of the high degree of linearity between remanent magnet flux and applied drive, AMP-MAD can store analog data indefinitely. The AMP Analog Transient Signal Recorder uses this property to meet display time requirements of the high- or low-speed oscilloscopes, pen recorders and electronic comparator circuits.

Toroidal Core Principles. Toroidal magnetic cores contain remanent flux (flux remaining after drive pulses is removed) whose direction is bi-stable. By applying a current through winding "A" of the core in Figure 1-a and 1-b the remanent flux in the core can be established as clockwise or counterclockwise.

The core is said to be in a "zero" state (Fig. 1-a) when all the remanent flux is in the CLEAR (clockwise) sense and a "one" state (Fig. 1-b) when all the remanent flux is in the SET (counterclockwise) sense. One of the limitations of conventional toroidal magnetic cores in storage applications appears during the readout of interrogation cycle. A toroidal core is "interrogated," or "read out," by application of a drive current in a direction to clear the core. On an output winding (B, Fig. 1-c) a voltage will be induced if remanent flux is switched by the interrogation pulse. If the remanent flux was already in the clear direction, no output voltage would be obtained. After an interrogate pulse the core is always left in the clear condition, i.e.—remanent flux clockwise—regardless of whether a "one" or a "zero" was read out of the element. This is called destructive readout. Where non-destructive output is required, most digital equipments utilize elaborate rewrite circuits that cycle the information back into the core after readout has taken

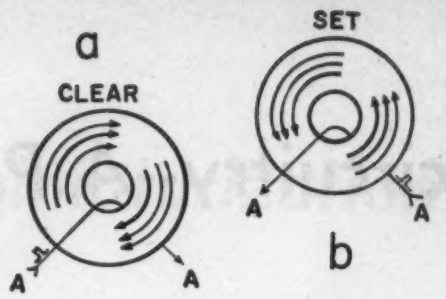

FIG. 1. READ-OUT of conventional toroids removes remanent flux.

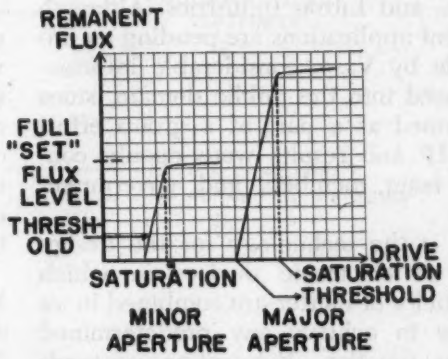

FIG. 2. MAJOR aperture requires more flux to set.

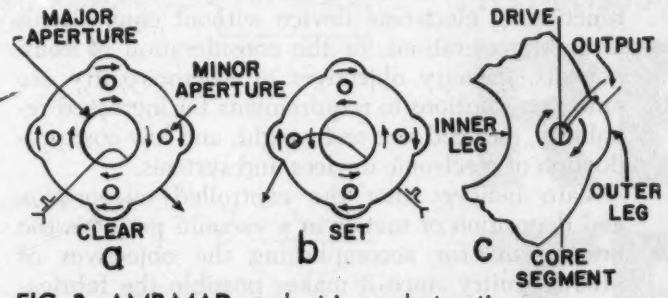

FIG. 3. AMP-MAD readout is nondestructive.

place. Since rewrite circuits require additional programming and since each additional piece of equipment increases costs and decreases reliability, the elimination of such rewrite cycling is highly desirable.

AMP-MAD Core Principles. Flux switching begins at the inner diameter (or shortest magnetic path) of a toroidal core and proceeds outward to the outer diameter (longer magnetic path) until the flux field is entirely reversed. For a given material, the switching threshold can be lowered by decreasing the inner diameter of the core and raised by increasing the inner diameter. Saturation drive can be affected by applying the same rule to the outer diameter. Through precise control of ferrite material, a linear relationship between drive and remanent flux can be achieved. Fig. 2 shows threshold and saturation points for both the major and minor apertures of a given core and depicts the linear relationship between "drive" and "remanent flux". The minor aperture threshold is significantly less than the major aperture threshold in that its path length is less (smaller I.D.).

Unlike conventional toroidal cores, a MAD core is "set" by reversing half of the total remanent flux. This point is shown in Fig. 2. By applying full "set" drive to the core shown in Fig. 3b, previously cleared in Fig. 3a, remanent flux is reversed on the major aperture to a point half way between the inner and outer diameters of the core. Now, remanent flux exists in a counterclockwise direction on the inner leg and clockwise on the outer leg of the core (see Fig. 3-c.

The intrinsic non-destructive output of a MAD core is a characteristic of its minor apertures in the "set" condition. If a minor aperture is threaded with a primary (drive) and secondary (output) winding, continuous non-destructive readout can be obtained on the output winding, transformer coupled to its primary winding by the outer leg of the minor aperture. In the "set" condition, the drive applied to the minor aperture primary winding switches flux locally around the minor aperture and is adjusted to a value less than the major aperture threshold level. In the "clear" condition and with controlled minor aperture drive, remanent flux cannot be switched around the minor aperture and thus no output can occur. Flux switched around a minor aperture does not destroy the "set" condition of the core. This is non-destructive readout. (*From 4-page technical bulletin, AMP Incorporated, Syscom Div., 932 So. 13th St., Harrisburg, Pa.*)

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*AMP-MAD is a trademark of AMP Incorporated.

Microcircuitry--*A Practical Technology for*

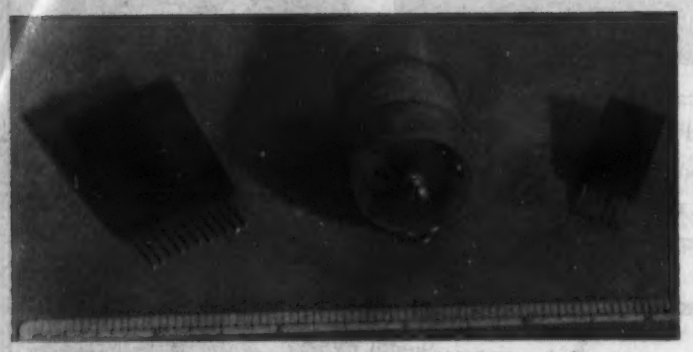

FIG. 1. MICROCIRCUITRY DEVICES—(left) 4-stage Flip-Flop Unit, (center) 27 mc Transmitter, and (right) Serial Adder.

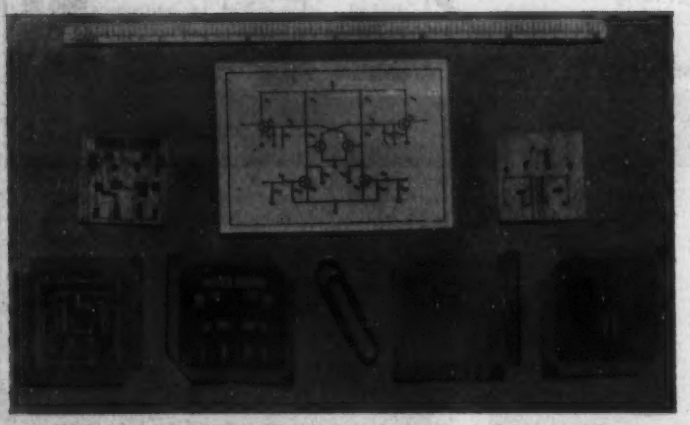

FIG. 2. SCHEMATIC, Morphology and Deposition Masks for Flip-Flop Unit.

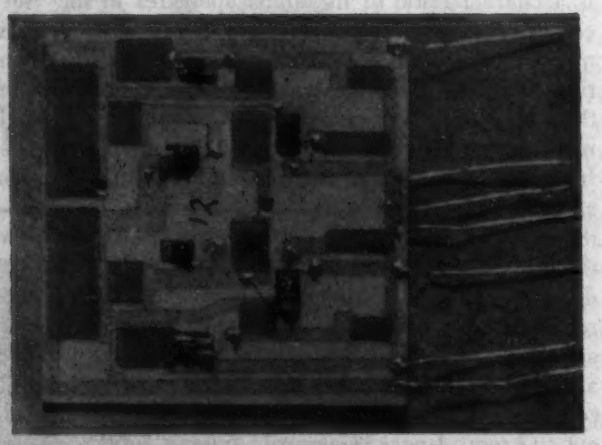

FIG. 3. SINGLE FLIP-FLOP, completed, is encapsulated with four similar wafers to produce 4-stage unit.

MICROCIRCUITRY was conceived by Varo Manufacturing, Inc., Garland, Texas, in 1951. Since 1955 Varo has been engaged in Microcircuitry research and development under the sponsorship of the Office of Naval Research and the Army-Navy Instrumentation Program (ANIP). Other companies within the immediate group ANIP effort with Varo are: The Douglas Aircraft Co. Servomechanisms, Inc., and Litton Industries. Although a number of patent applications are pending on improvements made by Varo, considerable information has also passed into the public domain, since work was performed as a part of a group effort financed by ANIP and results were openly contributed to all team members and government agencies.

Microcircuitry is the technology for the design and fabrication of electronic devices in which fundamental particles of matter are combined in an optimum manner to achieve any predetermined electrical transfer function. Fabrication proceeds directly from the fundamental particles to the functioning electronic device without connections, assembly operations, or the consideration of components. Primary objectives of Microcircuitry are optimum solutions to requirements for increased reliability, reduced size and weight, and low cost production of electronic devices and systems.

Varo believes that the controlled evaporation and deposition of metals in a vacuum provides the best means for accomplishing the objectives of Microcircuitry since it makes possible the fabrication of electronic devices of essentially unlimited complexity or functional capability in one continuous operation.

Since ultimate Microcircuitry objectives appeared too complex for immediate attainment, it was desirable to pursue the research effort in a manner that could rapidly attain useful interim states-of-the-art. Accordingly, thin film research was initiated for three major reasons: 1) Fundamental knowledge and techniques derived therefrom would directly apply to more sophisticated molecular assembly forms of the microcircuitry concept; 2) existing techniques for deposition of thin films provide a firm foundation for the requirements of Microcircuitry; and 3) the ability to use thin films of conducting, resistive, dielectric, and magnetic materials for practical passive electronic networks appeared to be attainable within a relatively short time.

Today Varo has achieved an interim state-of-the-art in which special semiconductors are assembled with the vacuum-deposited passive circuitry. These devices are inherently more reliable and smaller by an order of magnitude than the best component assembly.

Typical Interim Microcircuits

Fig. 1 shows three typical Microcircuitry devices which were demonstrated at the 1960 IRE convention in New York. At the left is a 4-stage high-speed flip-flop containing the equivalent of 104 components in a volume of 0.12 cubic inches. The center unit is a crystal-controlled citizen's band transmitter complete with microphone and 4 mercury cells. At right is a serial adder containing the equivalent of 85 components in 0.04 cu-in.

The Flip-flop represents a severe application for Microcircuitry. It operates from a 1 mc clock and delivers 2 watts to external loads while dissipating 2 watts internally. Temperature rise is 75°C above ambient. Operation in ambients of —55°C has been satisfactory, also preliminary shock, vibration and humidity test results are good.

The first step in microcircuitry design is to establish a conventional schematic which is breadboard assembled and tested (Fig. 2). In the circuit design, inductive components are eliminated or minimized, capacitances limited to less than 0.05 μf and resistances to less than 20,000 ohms, wherever possible.

The next step is to decide upon morphology or package configuration. Substrates of rectangular or circular shape of approximately 1 sq-in area are preferred for fabrication in existing deposition chambers. Two or more substrates are commonly stacked and encapsulated for structural strength.

A substrate 1″ square was selected to accommodate one complete flip-flop. Masks for the deposition process are prepared from brass, copper or stainless-steel by photo-etching. Slots and holes are drilled in the cleaned substrate with the aid of dental sandblast tools. The substrate is then cleaned and placed in the vacuum deposition chamber.

The substrate materials of special barium titanate provide high dielectric constants to permit the formation of capacitances using opposing conducting film areas. Nichrome films approximately 1000Å thick provide a stable resistivity of 100 ohms per square. Gold films provide conducting areas and paths.

for Reliable Microminiaturization

The deposited substrate is checked with indium probes for proper circuit values. Transistors are imbedded in the substrates and connected to appropriate conducting areas with conducting epoxy. Circuit operation is checked and the substrate is dip-coated with silicone varnish and baked (Fig. 3). Fine wire leads between substrates and for external leads are connected with solder or conducting epoxy. Substrates are separated by thin mylar sheets, connected to an epoxy terminal board and encapsulated.

Development Technologies and Future Outlook

Now undergoing development are methods of dielectric deposition, which will remove the present limitation of capacitance values; semiconductor deposition and etching, which will permit the formation of diodes and transistors integral with the passive elements; deposition of magnetic films to make inductors and transformer fabrication practical; and multigun deposition equipment which will permit deposition of passive circuitry for up to six or more devices in one chamber pump-down. Such production process should lend themselves to automatic programming for the rapid and economical production of complete devices.

Future applications of the deposition process are expected to include functions such as electroluminescence, photoelectrics, thermoelectrics, memory, sensors, etc. Each advance in the state-of-the-art can be independently incorporated into the Microcircuitry design and fabrication process.

The approaches to and generic names for the ultimate Microcircuitry are varied; each has its merits and contributes to the knowledge which is a common requisite. The combined technologies are now sufficiently advanced to achieve reliability and size reduction which are orders of magnitude better than the most sophisticated component assembly. The growing number of organizations engaged in fundamental and applied Microcircuitry research assures the continued rapid advance in knowledge and techniques. The Microcircuitry concept, its rapid acceptance and rapid rise to prominence portends a revolution in the electronics industry without parallel or precedent. (*From* 10-*page paper, "Microcircuitry", Varo Mfg. Co., Inc., Garland, Texas*)

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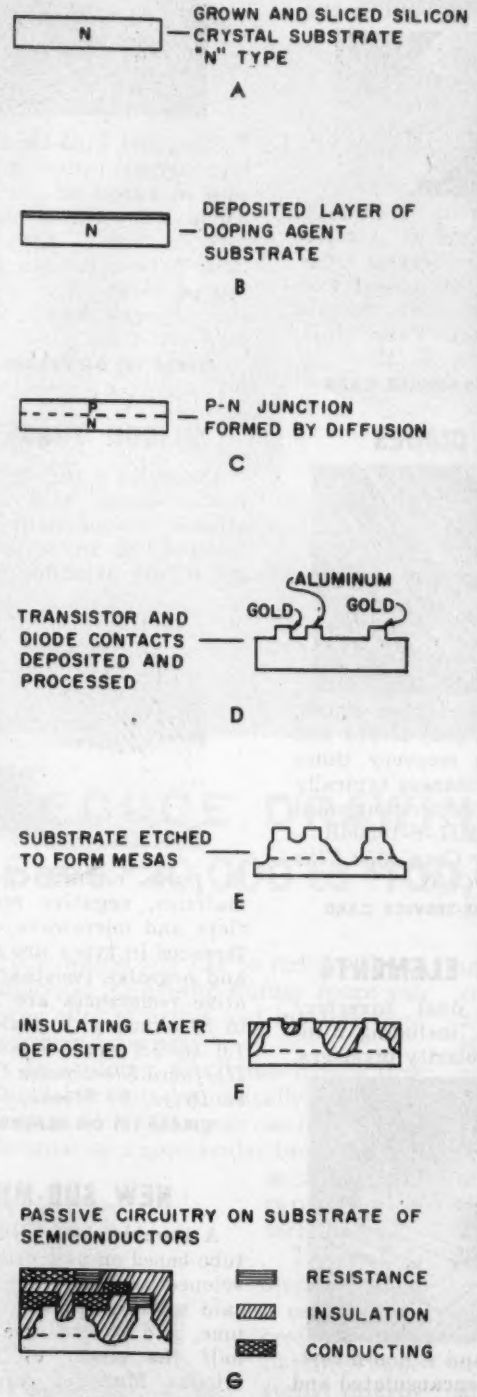
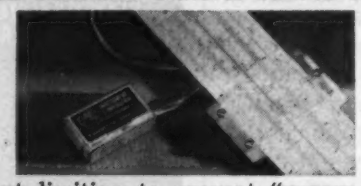


FIG. 4. POSSIBLE TECHNIQUE for fabricating MICROCIRCUITRY devices on semiconductor substrates. Each advance in the state-of-the-art contributes to the versatility of the concept.

MSD new products

SERVO TRANSISTOR AMPLIFIER

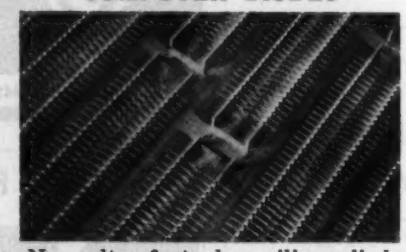
New moderate temperature, medium gain transistorized amplifier with high gain stability for severe vibration conditions features built-in cur-



rent limiting to prevent "runaway". Unit cannot be damaged by shortcircuited output or power reversal. Open loop gain is over 40 db, closed loop gain is 10 to 26 db.—*Mr. Ronald Oldenburg, Section 242, Taber Inst. Corp., No. Tonawanda, N. Y.*

CIRCLE 117 ON READER-SERVICE CARD

COMPUTER DIODES

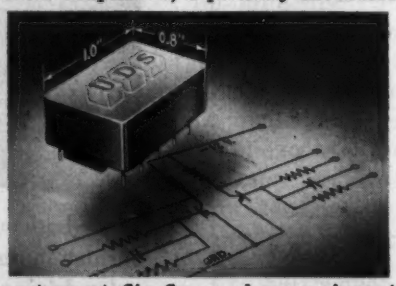


New ultra-fast glass silicon diodes, types 1N903—1N908, plus 1N914 and LN916, feature max recovery times of 4 mμsec and capacitances typically less than 1$\mu\mu$f. Exceed environmental requirements of MIL-S-19500B.—*Rheem Semiconductor Corp., 350 Ellis St., Mountain View, Calif.*

CIRCLE 118 ON READER-SERVICE CARD

SUB-MIN LOGIC ELEMENTS

New Multi-mode dual inverter/shifter Type MM-2A, including 2 inverter amplifiers, 2 polarity inverters,

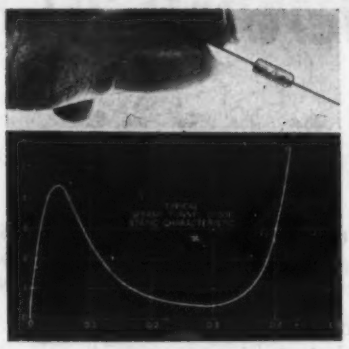


a setpreset flip-flop and a non-inverting amplifier. Epoxy encapsulated and meeting Mil-specs, the unit is only 1" long x 0.8" x 0.5" high.—*Universal Data Systems, Inc., subsid., Becker Electronics Mfg. Corp., 1091 Rockaway Ave., Valley Stream, N. Y.*

CIRCLE 119 ON READER-SERVICE CARD

TUNNEL DIODE SERIES

Five new tunnel diodes, said to comprise the widest range of typical peak currents available, are the T101-0.8 ma; T102-1.5 ma; T103-3.5 ma; T104-

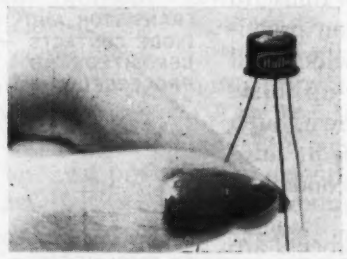


7.0 ma; and T105-15. ma. Peak to valley current ratios on all types are said in excess of 5.0 to 1, typically 8.0 to 1. Operating storage temperature is from —55° to 100°C. The units have a 100 mw dissipation rating at 25°C.—*Sperry Semiconductor Div., Sperry Rand Corporation, So. Norwalk, Conn.*

CIRCLE 120 ON READER-SERVICE CARD

SILICON TUNNEL DIODES

Types HT-1 through HT-10 Silicon tunnel diodes, said to be the first offered commercially, designed for operation in ambients from —85° to 200°C, are available for applications



in pulse circuits, gating, memory matrices, negative resistance amplifiers and microwave oscillators. Differences in types are in peak current and negative resistance. Typical negative resistances are from 220 down to 38 ohms, with peak currents from 1.0 to 5.6 ma.—*Semiconductor Div., Hoffman Electronics Corp., 1001 Arden Drive, El Monte, Calif.*

CIRCLE 121 ON READER-SERVICE CARD

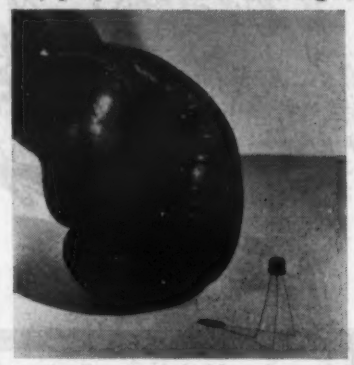
NEW SUB-MIN TUBE

A thimble-sized "Nuvistor" vacuum tube based on new design concepts developed by RCA research engineers is said to take up only $\frac{1}{10}$th of the volume, and to consume less than one-half the power of its present-day triodes. Made of ceramic materials, steel, molybdenum and tungsten, the tube can withstand high shock and vibration.—*Electron Tube Div., Radio Corporation of America, Harrison, N. J.*

CIRCLE 122 ON READER-SERVICE CARD

HI-SPEED SWITCH TRANSISTOR

New 2N1473 switching transistor designed for use in telemetered torpedoes, projectile fuses and high-im-

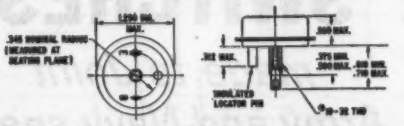


pact missiles is capable of operating during and after 20,000 G accelerations. It also performs critical switching functions up to 400 ma Ic. Full characteristics and ratings on request. —*Semiconductor Div., Sylvania Electric Products Inc., Woburn, Mass.*

CIRCLE 123 ON READER-SERVICE CARD

POWER TRANSISTORS

"Highest-rated" power transistors commercially available is claim for new 2N1522 and 2N1523 at 50 amperes, with low saturation voltage of

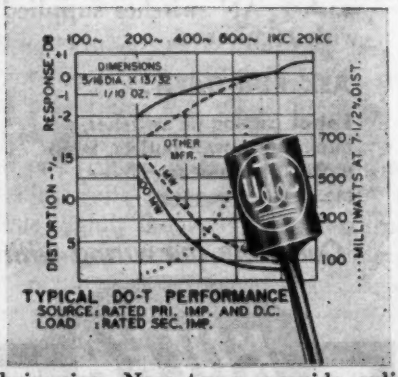


½ v, and max resistance of 0.01 ohm at 50 amp I_c. Other new units are 2N1520 and 2N1521 with I_c of 35 amps, while 2N1518 and 2N1519 are rated at 25 amperes. Engineering data sheets on request.—*Delco Radio Div., General Motors Corp., Kokomo, Ind.*

CIRCLE 124 ON READER-SERVICE CARD

TRANSISTOR TRANSFORMERS

New DO-T transistor transformers are hermetically sealed items having power handling capability 10 to 100 times greater than other units twice



their size. New types provide split secondaries for balancing required when driving transistors. 44 types covering all medium and low-level transistor applications now available.—*United Transformer Corp.*, 150 *Varick St., New York 13, N. Y.*

CIRCLE 125 ON READER-SERVICE CARD

POWER TRANSISTORS

New Silicon intermediate power transistors, Types 2N1047 to 2N1050, are of diffused-junction NPN conformation, designed for power switching and amplifier applications in the −65°C to 200°C temperature range. V_{cc} is from 80 to 120 v, with power dissipation of 40 watts at case temperature. Meet MIL-E-19500B.—*Silicon Transistor Corp., Carle Place, N. Y.*

CIRCLE 126 ON READER-SERVICE CARD

MINIATURE VR TUBE

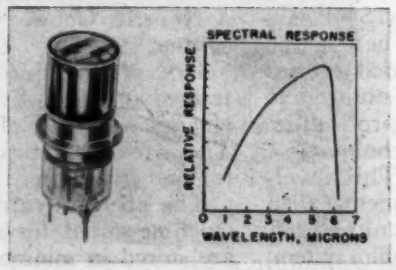
New line of miniature high-voltage vacuum tube voltage regulators with pentode configurations, capable of

handling 1,000, 4,000 and 10,000 v, are also useful as power amplifiers in high voltage equipment.—*Victoreen Instrument Co., Cleveland, Ohio.*

CIRCLE 127 ON READER-SERVICE CARD

SCANNING IR DETECTOR

New IR Type J-02 detector of extremely small area (0.1mm x 0.1mm) uses the indium antimonide photovoltaic effect at liquid Nitrogen temperatures giving NEP values of 2×10^{-12} at 5 microns and 7×10^{-12} watt for 500° K blackbody. Response from the

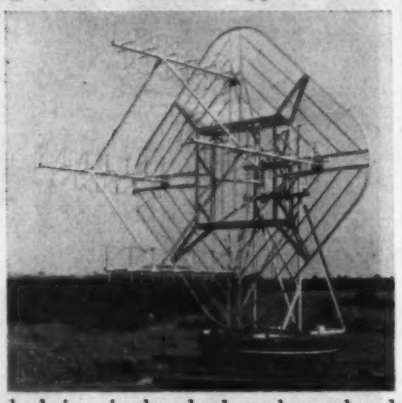


visible region to 5.7 microns is with a time constant of less than 1 μsec, permitting its use in high resolution rapid scanning designs.—*Radiation Electronics Co., 5600 Jarvis Ave., Chicago 48, Ill.*

CIRCLE 128 ON READER-SERVICE CARD

HELIX ANTENNAS AND REFLECTORS

New extended line of helix antennas and matching reflectors, including 4, 6, 8 and 10-turn types are furn-



ished in single, dual and quadruple assemblies. Polarization is circular for orbital body telemetering and other airborne communications. Manual and remote controlled mounts also supplied.—*Technical Appliance Corp., Sherburne, N. Y.*

CIRCLE 129 ON READER-SERVICE CARD

TIMING CONTROL MODULES

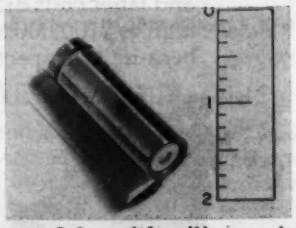
New subminiature modules providing applications in precision timing control, logic, and programming

equipment are available in fixed and adjustable types as individual "building blocks". Time delays from 0.00005 sec to 300 sec are available. Detailed characteristics on request.—*Tempo Instrument Inc., P. O. Box 338, Hicksville, N. Y.*

CIRCLE 130 ON READER-SERVICE CARD

P-TYPE IR DETECTOR

New QK-748 P-type gold-doped germanium infared detector has spectral sensitivity of 2-6μ with sapphire

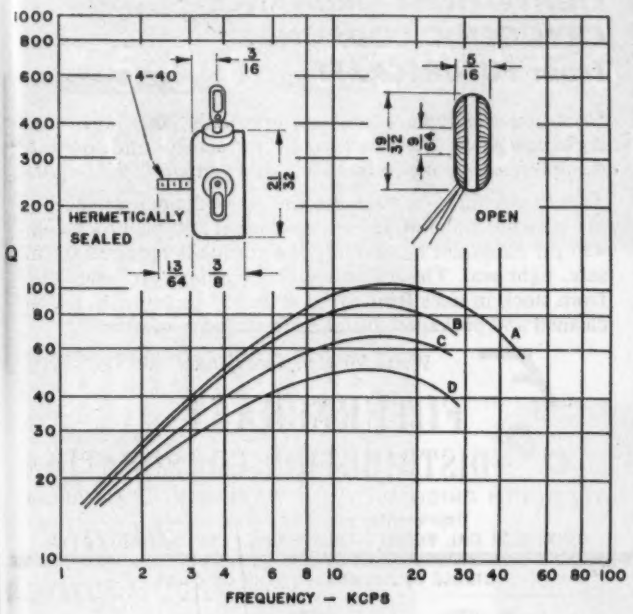


windows, 2-9μ with silicon windows. Operates with Santa Barbara Research Cooler at liquid nitrogen temperature (78°K) with response of $D^* = 5 \times 10^9$ cm/watt, and time constant less than 1 μsec.—*Microwave & Power Tube Div., Raytheon Company, Waltham 54, Mass.*

CIRCLE 131 ON READER-SERVICE CARD

Inductor Design Data File

A convenient loose-leaf reference guide to performance characteristics of filters, magnetic amplifiers, and torodial coils engineered and produced to military and customer's specifications by Components Corp., 2857 No. Halsted St., Chicago 14, Ill., is available on request. Different colors are used for data sheets for the three classes of products, enclosed in a cover which serves as a filing jacket.



TYPE 0300-A0 INDUCTOR • Q VS FREQUENCY AT CONSTANT FLUX DENSITY.

Curve	L (mhy)	$I_{rms}\sqrt{L}$ (amps$\sqrt{hy}$)
A	50	.003
B	250	.01
C	250	.1
D	250	.5

C, nominal dist. = 200$\mu\mu$f

R_{dc} nominal = 500 ohms/hy

L range = 5 mhy to 1.5 hys

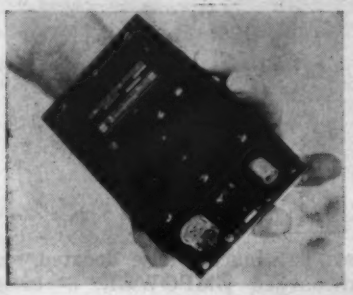
Wave Filters cover all types for separating frequency bands up in the 0 to 500 kc region, including band pass filters and oscillator tanks used in missile control applications, complementary filters, narrow band pass filters, discriminators and low pass filters. Toroidal Coils ranging from 3/16" OD to 5" OD include high-Q inductors, IF transformers, dc-dc converter transformers, pulse transformers, output transformers, 400 cps filament transformers, and many other uses designed to customer specifications. Magnetic Amplifiers are designed in close liaison with the consumer, covering servo motor control, relay control, voltage regulator and other applications.

Information provided in data sheets includes characteristic curves, dimensions and other design data similar to that shown for the Type 0300-A0 inductor, illustrated.

FOR MORE INFORMATION CIRCLE 132 ON READER-SERVICE CARD

SATELLITE TRANSMITTER

Tiros weather satellite uses two Model 3115 FM telemetry transmitters to relay cloud-cover pictures to

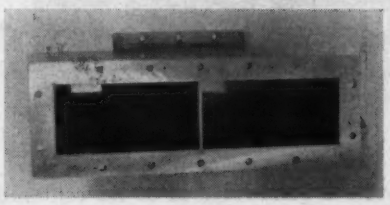


earth. Operated at 235 mc, and weighing only 33 oz., each transmitter is completely sub-miniaturized, producing frequency modulation at low frequency with wide deviation, where S/N ratio is high. Output is 2 watts power.—*Radiation Incorporated, Melbourne, Fla.*

CIRCLE 133 ON READER-SERVICE CARD

"MOLD-IN" TERMINATIONS

High Power Terminations can now be installed in customer-furnished waveguide and coaxial assemblies by

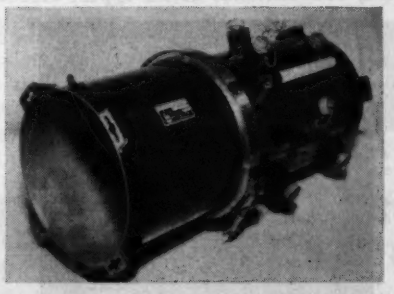


ceramic-base microwave power absorbers molded in place for high power capacity without artificial cooling. Small lot deliveries approximately 72 hrs.—*Radar Design Corp., Syracuse, N. Y.*

CIRCLE 134 ON READER-SERVICE CARD

ANTENNA TEST COUPLER

New No. 9322 Radar performance monitor covering range of 1000-11,000

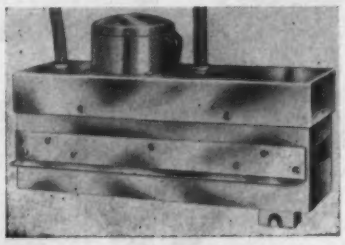


mc "matches out" countermeasure antennas of all types, providing a 40db ± 2.5 db calibrated signal over a frequency range more than 10 kmc wide, which is accessible for power and frequency checks through coupling devices. Variation in VSWR from free space to antenna coupler is less than 0.12 over a 200% bandwidth.—*Bogart Mfg. Corp., 315 Siegel St., Brooklyn, N. Y.*

CIRCLE 135 ON READER-SERVICE CARD

STEP ATTENUATOR

New automatic step attenuators for rapid change of microwave attenuation values or where attenuators

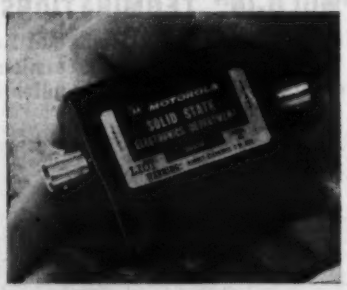


must be inaccessibly located, are trademarked EMPOWER. 6- or 12-step attenuations from 0.1 db to 60 db, and from 1 to 4 watts RF power operating from 28v dc power source, are available.—*Empire Devices Products Corp., Amsterdam, N. Y.*

CIRCLE 136 ON READER-SERVICE CARD

COMPACT UHF ISOLATOR

New ferrite isolator Model LI-01, for operation in the 440-470 mc band



covers a bandwidth of 30 mc centered at 455 mc, providing more than 10 db isolation with less than 1.0 db insertion loss.—*Solid State Electronics Dept., Motorola, Inc.*, 8201 *East McDowell Rd., Scottsdale, Ariz.*

CIRCLE 137 ON READER-SERVICE CARD

LARGE FLEXIBLE WAVEGUIDE

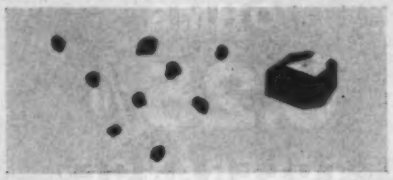
New All-Aluminum flexible waveguides in large sizes with operating characteristics as good as, or better than, conventional brass types, effect

large weight reductions with elimination of non-compatible materials, fluxes, plating and cleaning solution entrapment through Balanced-Phase® construction.—*E. M. T. Corp., Newton, N. J.*

CIRCLE 138 ON READER-SERVICE CARD

MICROWAVE GARNETS

Single Crystals of Gallium substituted Yttrium Iron Garnet having applications in magnetically tunable microwave filters, passive microwave



power limiters and 3-level T-W masers are now available in two types. One type has saturation magnetization of 1000 gauss/cc, with Curie temperature at 206° ±2°C; while the other saturates at 600 gauss/cc and has a Curie temperature of 160°C. Both types have linewidth of not more than one oersted at C Band frequencies.—*Microwave Chemicals Laboratory, Inc.*, 282 *Seventh Ave., New York* 1, *N. Y.*

CIRCLE 139 ON READER-SERVICE CARD

CHARACTER GENERATOR

New All-Electronic generator for alpha-numeric characters generates cathode-ray tube deflection and inten-

sification voltages to print characters on one or many display tubes. Characters photographed from tube face are shown. 2-page technical bulletin on request.—*Skiatron Electronics & Television Corp.*, 180 *Varick St., New York* 14, *N. Y.*

CIRCLE 140 ON READER-SERVICE CARD

400-CPS STANDARD

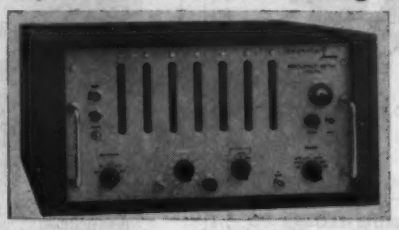
New stable secondary frequency source of 400 cps, Model L, is crystal-controlled oscillator synchronizing a relaxation type oscillator driving a

binary. The binary in turn drives a tuned power output stage (sine wave) or a square wave amplifier, keeping frequency within ± 0.015% over the —55° to 100°C. range. Meets Milspecs.—*Time Control Systems Div., Designers for Industry, Inc.*, 4241 *Fulton Pkwy, Cleveland* 9, *Ohio.*

CIRCLE 141 ON READER-SERVICE CARD

DIGITAL FREQ-METER

New Model 7175 digital frequency meter measures any frequency from 10 cps to 110 megacycles to an accuracy of .00003% ±0.1cps; sensitivity is 100 mv rms. Consisting of



10 mc counter integrated with a hetrodyne frequency meter; measurements are made by selecting a reference frequency in mc to be added to digital counter display in cps.—*Berkeley Div., Beckman Instruments, Inc., 2200 Wright Ave., Richmond, Calif.*

CIRCLE 145 ON READER-SERVICE CARD

TRANSISTORIZED TRANSMITTER

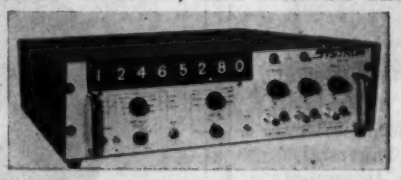
New phase-modulated telemetry transmitter, type TRPT-250, weighing about 9 oz has an output of 0.25 watt nominal in the 215-260 mc range.

Using available transistors, and requiring 28v ±10% at 80 ma dc power, it is said to be capable of transmitting data from any subcarrier system in aircraft, missiles or space craft.—*Vector Manufacturing Co., Inc., Keystone Rd., Southampton, Pa.*

CIRCLE 146 ON READER-SERVICE CARD

10MC COUNTER-TIMER

New fully transistorized Model 1039 Counter-Timer designed for industrial and military applications provides measurements of frequencies from 0 to 10MC, time intervals and



periods from 0.3 μsec to 10^8 sec, frequency ratios to 10^7 and phase measurements direct to 0.1°. Features exclusive Nixie In-Line readout, 3 dc amplifiers with 1 megohm input impedance and 0.1 vrms sensitivity, in a panel height of only 5¼"; uses only 50 watts power.—*Systron Corporation, 950 Galindo St., Concord, Calif.*

CIRCLE 147 ON READER-SERVICE CARD

SPECTRUM ANALYZER

New SPA-4 Spectrum Analyzer has sensitivity exceeding 100 dbm over the 10mc—44 kmc range. Eight push-button frequency range selector automatically couples the selected band's proper mixer and oscillator, also illuminates the slide rule dial scale and the applicable input connector. Bandwidth is variable from 1 kc to 80 kc for analyzing wide or narrow pulsed RF signals.—*Panoramic Radio Products, Inc., 514 So. Fulton Ave., Mount Vernon, N. Y.*

CIRCLE 148 ON READER-SERVICE CARD

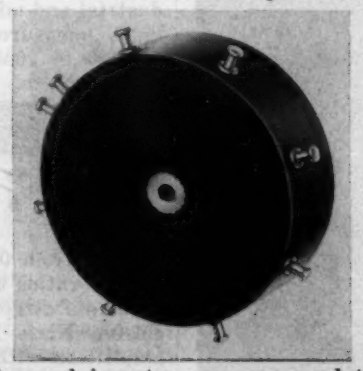
SCHERING BRIDGE

New High Voltage Schering Bridge for measuring power factor and capacitance of electrical insulating materials when subjected to high voltage stress is available in General Purpose and Cable Test Models. Dielectric constant, loss factor and other values may be calculated from measured parameters and physical dimensions of sample. Capacitance accuracy is ±0.2% and tangential accuracy 2% and better.—*Industrial Instruments, Inc., 89 Commerce Rd., Essex Co., N. J.*

CIRCLE 149 ON READER-SERVICE CARD

TOROIDAL TRANSFORMERS

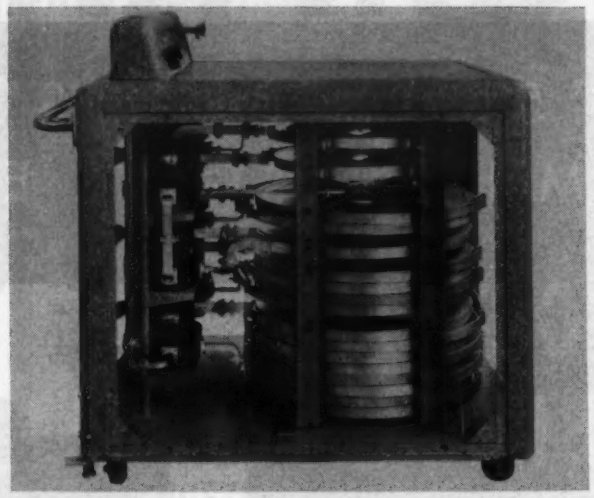
New encapsulated toroidal transformers for transistorized power supplies and inverters are encapsulated to perform satisfactorily in ambients from −55° to 130°C.—*Barker & Williamson, Inc., Bristol, Pa.*



CIRCLE 150 ON READER-SERVICE CARD

X-Band Variable Delay Line

A new X-band microwave delay line, variable in steps from 13 ft to 1228 ft, now provides 64 different ranges in a compact, stable and quickly-switched test stand. The new test instrument, shown with side panels removed, essentially consists of a series of lengths of coiled rigid rectangular waveguides arranged for interconnection by solenoid-operated high isolation waveguide switches.



TECHNIQUES of coiling and switching wave guides were essential in the development of this portable variable microwave delay line built to Diamond Ordnance Fuze Laboratory specifications by Turbo Machine Co., Lansdale, Pa.

The variable delay line was originally developed by the Diamond Ordnance Fuze Laboratories, Ordnance Corps, Department of the Army, using straight lengths of waveguide which were hand-coupled to change the delay value for a test set-up. Two or more days were required to test 64 different ranges with such an arrangement. During this time measurements were usually in doubt because amplifiers and other components tended to drift appreciably during a day-long checkout. Waveguide delay lines are preferred at microwave frequencies because greater delays are obtainable with less attenuation, less insertion loss, and are not frequency selective.

Further development by DOFL and engineers at Turbo Machine Co., resulted in a method of coiling the waveguides and in cleaning and finishing interior waveguide surfaces to provide minimum distortion of the waveguide to reduce discontinuities and unwanted internal reflections. Turbo is also credited with original ideas for the coupling of coils within the waveguide assembly, which permits fast and accurate changing of waveguide lengths.

With the new equipment, there is far less time for drifting of amplifiers and control circuits. In fifteen minutes time all 64 different ranges can be checked out, enabling engineers to take many more measurements, and more accurate tests. The portability of the new equipment, mounted in a test cart, permits transportation of the delay line to any test area, rather than requiring the movement of all delicate laboratory

breadboards to the stationary site of the waveguide delay line.

The X-band test stand is now available to laboratories which require a simple, accurate and reliable means of testing response up to 1200 ft. The Turbo Machine Co., Lansdale, Pa., acknowledges the contributions in development of coiled microwave delay lines and the development of techniques for testing and evaluation of electrical characteristics of the coils, of the following personnel of the Diamond Fuze Laboratories: R. R. Palmisano, A. Sherman, Ray Warren, H. S. Jones, H. K. Morlock, Irving Flyer, and Solomon Levine.

FOR MORE INFORMATION CIRCLE 151 ON READER-SERVICE CARD

New Diodes Operate at 200°C

Operating at temperatures of 200°C, said to be the highest yet feasible for a subminiature silicon diode/rectifier, Types MP100 through MP600 diodes are being made available in production quantities by the General Instrument Corporation. The new diodes are of fused junction construction encased in hermetically-sealed glass (0.300″ long and 0.105″ diameter), and are particularly useful in miniaturized applications.

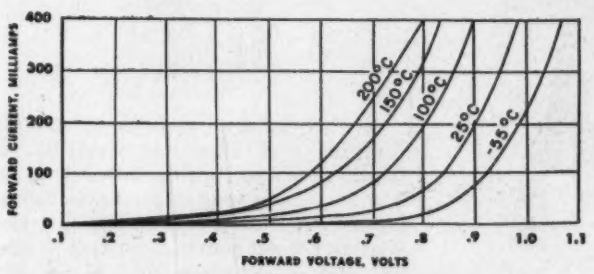


FIG. 1. FORWARD CURRENT vs forward voltage characteristic Type MP Series Silicon Diode Rectifier at typical ambient temperatures.

TABLE I. ELECTRICAL DATA SERIES MP SILICON DIODE/RECTIFIERS

Type	PIV (Volts)	Dc Output Current (Ma)*	Current (μa) @ PIV		Forward Voltage Drop (Volts) @ 400 Ma. @ 25°C.	
		25°C.	200°C.	25°C.	200°C.	
MP 100	100	400	50	.05	75	1.0
MP 225	225	400	50	.05	75	1.0
MP 300	300	400	40	.05	75	1.0
MP 400	400	400	35	.05	75	1.0
MP 500	500	400	25	.05	75	1.0
MP 600	600	400	20	.05	75	1.0

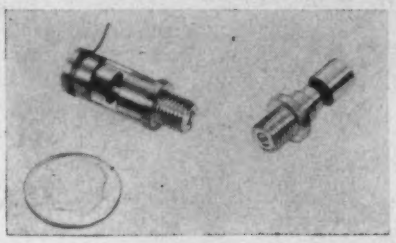
*Resistive or Inductive Load

Characteristics of the MP series are given in the accompanying table, which data are also graphically shown in the forward current/voltage curves (Fig. 1). The new units meet military specifications, cover the range from 100 to 600 PIV and operate at ambient temperatures from −65° to 200°C. For example, at 200°C and 225 PIV, maximum average rectified current is 50 ma. (*From new 8-page data folder covering MP and 1N645-1N649 silicon diode rectifiers, General Instrument Corp., Semiconductor Div., 65 Gouverneur St., Newark 4, N. J.*)

FOR THIS LITERATURE CIRCLE 152 ON READER-SERVICE CARD

TRIMMER CAPACITOR

New miniature trimmer capacitor having absolute retrace characteristic,

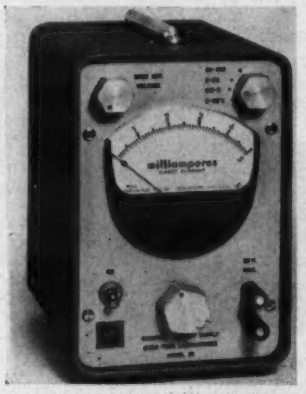


high-Q, and virtually zero temperature characteristic is said to offer a new order of absolute capacitance control.—*Atlee Corp., 47 Prospect St., Woburn, Mass.*

CIRCLE 153 ON READER-SERVICE CARD

CONSTANT CURRENT SUPPLY

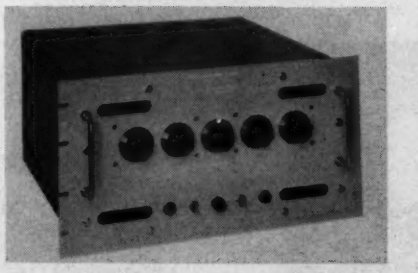
New power supply Model 151 provides constant current regardless of voltage drop across load. Output of the unit is 0.5 to 500 ma in three



ranges regulated to within 0.25% on 0 to 20 v load and for 105 to 125 v ac line. Open circuit voltage can be set at any max value from 2 to 20 v, and open circuit voltage read on panel meter by flip of panel switch.—*Quan-Tech Laboratories, 60 Parsippany Blvd., Boontown, N. J.*

CIRCLE 154 ON READER-SERVICE CARD

CURRENT GOVERNOR

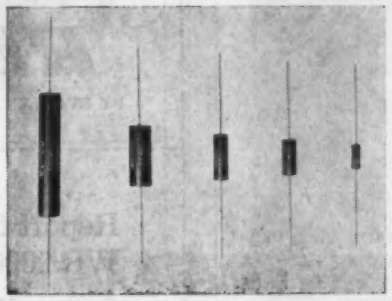


New programmable constant current source CS-12, is designed to serve as an accurate source for meter calibration, transistor and diode forward testing, etc. Current is set to five places by decade knobs, is accurate to 0.05% ± 1 μa from 10 μa to 1 amp for voltages from 0 to 7 v dc.—*North Hills Electric Co., Inc., 402 Sagamore Ave., Mineola, N. Y.*

CIRCLE 155 ON READER-SERVICE CARD

CARBON FILM RESISTORS

New design of carbon film resistors meet the requirements of MIL-R-10509C Characteristic B. A dry air

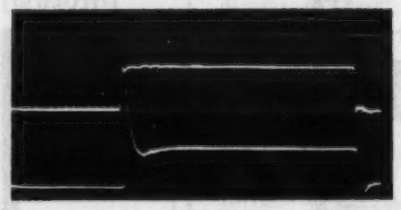


space between the epoxy tube and resistive element prevents moisture transmission to film during extended storage in high humidity.—*Mepco, Inc., Morristown, N. J.*

CIRCLE 156 ON READER-SERVICE CARD

HF RESISTOR

A precision wire-wound Ultraohm resistor designed for high frequency circuits has unusually low capacitance and inductance, low temperature coefficient and low tolerance. Rise time for Ultraohm Model 207AC resistor

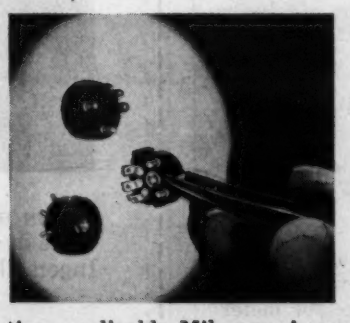


is compared in upper oscilloscope trace with inductive kick from standard resistor in lower trace. Values from 10 ohms to 1 megohm with axial or radial leads or special printed circuit prongs are available, all exceeding MIL-specs.—*Ultronix, Inc.*, 111 *E. 20th Ave., San Mateo, Calif.*

CIRCLE 157 ON READER-SERVICE CARD

HI-TORQUE MINI POT

High torque version of Model 6 variable resistor designed to hold adjustment under severe vibration and

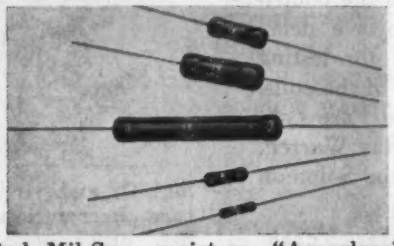


meeting applicable Mil-specs is available to the orginal equipment market, in resistances of 500 ohms to 10 megohms. Detailed data in Bulletin EP-893.—*Centralab, the Electronics Div., of Globe-Union, Inc.*, 900 *E. Keefe Ave., Milwaukee* 1, *Wisc.*

CIRCLE 158 ON READER-SERVICE CARD

SOLID CONFORMAL RESISTOR COAT

Exclusive "Aeroglaze" 100% solid conformal coating now gives superior mechanical protection and performance characteristics to carbon-depos-

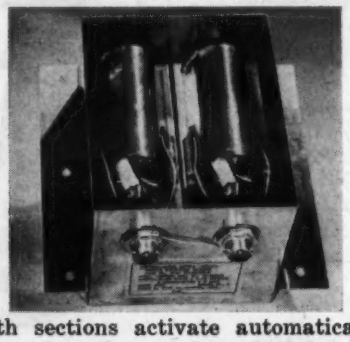


ited Mil-Spec resistors. "Aeroglaze" resistors are available in ⅛, ¼, ½, 1 amd 2 watt sizes from 5 ohms to 50 megohms.—*HiQ Division, Aerovox Corp., Olean, N. Y.*

CIRCLE 159 ON READER-SERVICE CARD

DUAL Ag-Zn BATTERY

New dual silver-zinc battery, Model P43A with two 19-cell sections each providing 3 amp at 26.5 v, meets need for supply of steady load while other section supplies heavy peak demands.

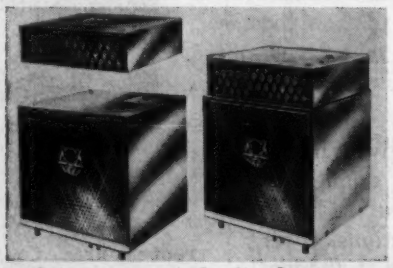


Both sections activate automatically from electrolyte tank and piston actuated by solid propellant gas within 0.5 sec.—*Cook Batteries, Subsidiary of Telecomputing Corp.*, 3850 *Olive St., Denver* 7, *Colo.*

CIRCLE 160 ON READER-SERVICE CARD

OPTIONAL REGULATION

Changing the regulation of a power supply without rewiring or moving from its mounted position is readily accomplished with Victory Variant regulator. Alone the power supply operates as a 1% regulated unit. With



regulator mounted it becomes a ±0.25% or ±0.05% regulated supply (right). Also the regulator units may be used separately. When supplied with input volts from 9-16 v dc the output is held to 6.3 v dc ±.25% or ±0.05%.—*Victory Electronics, Inc.*, 50 *Bond St., Westbury, N. Y.*

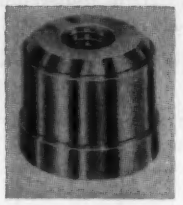
CIRCLE 161 ON READER-SERVICE CARD

MICRO-MIN RELAYS

New Type 30 microminiature relays for computer systems, missile or aircraft and communications circuitry, are available in 13 standard types and 12 standard coils. Although weighing only about ½ oz, the contacts are rated to a max 3 amp, 26.5 v dc, 500,000 operations at 2 amperes, and operate in 5 milliseconds max.—*Phillips Control Corp.*, 59 *West Washington St., Joliet, Ill.*

CIRCLE 173 ON READER-SERVICE CARD

QUARTZ LOAD CELL



New Type 510 Quartz Load Cell, features high capacity, excellent repeatability and rigidity in small package for rocket engine thrust measurements. Auxiliary equipment includes Kistler Electrometer Amplifier, Model 651 Piezo-Calibrator, and Model 651 Low Noise Cable.—*Kistler Instrument Corp., No. Tonawanda, N. Y.*

CIRCLE 174 ON READER-SERVICE CARD

SUBMIN LATCHING RELAY

New 10 amp magnetic latching relay in submininiature BR-9 series operates on as little as 100 mw, is shock rated at 50 G, 11 msec with 30 G vibration, 10-2000 cps, yet weighs only 1 oz. Meets MIL-R-5757C and 25018 specifications.—*Babcock Relays, Inc.*, 1640 *Monrovia Ave., Costa Mesa, Calif.*

CIRCLE 175 ON READER-SERVICE CARD

MERCURY-WET SWITCH

New Type HGX-1003 mercury-wetted contact switch is designed for applications where it may be actuated by

a permanent magnet. Hydrogen pressurized capsule is sealed in glass and potted in impregnated paper tube. Has a capacity of 5 amp max, 500 v max, 250 va.—*C. P. Clare & Co.*, 3101 *Pratt Blvd., Chicago* 45, *Ill.*

CIRCLE 176 ON READER-SERVICE CARD

SCINTILLATION DETECTOR

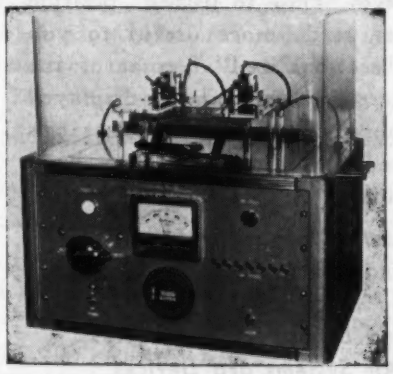
New gamma-ray Survey Meter Model 15, with spherical 8-in plastic scintillator has sensitivity of 15,000 cpm above 0.15 Mev at sea level, 100,000 cpm above a pulse level of

0.10 Mev in a radiation field of 0.04 mr/h produced by Cobalt 60. Pulse height discrimination is available. Applicable in airborne and balloon surveys because battery operated; cabinet form is illustrated.—*Franklin Systems, Inc., 2734 Hillsboro Rd., West Palm Beach, Fla.*

CIRCLE 142 ON READER-SERVICE CARD

ARC RESISTANCE TEST

New Model 8540 Arc Resistance Tester for research and quality control applications provides 15 kv at 60



ma ac in accordance with ASTM D-495 and Federal LP406B Specifications. Electrode assembly, specimen holder and jig for sharpening electrodes are also provided.—*Associated Research, Inc., 3777 W. Belmont Ave., Chicago, Ill.*

CIRCLE 143 ON READER-SERVICE CARD

PHASE-LOCK DISCRIMINATOR

New Model 167A subcarrier discriminator for FM telemetry is said to provide true 60 db dynamic input

voltage range; better than 100:1 improvement ratio for tape-speed compensation; and employs lowpass output filters which compensate for servo characteristics.—*Electro-Mechanical Research, Inc., Sarasota, Fla.*

CIRCLE 144 ON READER-SERVICE CARD

RATE TURNTABLE

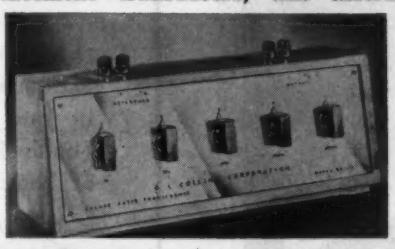
Model T-844 Rate Turntable is a compact, portable test unit for mounting rate gyros, antennas, guidance

assemblies requiring constant rates-of-turn for performance checks. Catalog 152 on request.—*Sterling Precision Corp., 17 Matinecock Ave., Port Washington, N. Y.*

CIRCLE 235 ON READER-SERVICE CARD

RATIO TRANSFORMER

New Model DRT-5 Decade Ratio Transformer developed to accurately certify differential transformer displacement transducers, this instru-



ment also calibrates ac meters, ratio boxes, attenuators, amplifiers and transformers to ratio accuracy of better than 0.001%.—*G. L. Collins Corp., 2820 East Hulett St., Long Beach 5, Calif.*

CIRCLE 236 ON READER-SERVICE CARD

NAV-COMM TRANSCEIVER

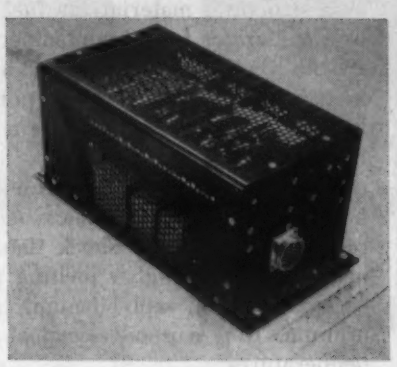
Simultaneous transmit/receive communications and navigational reception is provided in a single unit, the King KX-100. 10-watt transmitter, and com-

munications receiver are simultaneously tuned, 100 channel navigation receiver is separately tuned. Optional Omni-Localizer Converter-Indicator may be placed on panel with flight instruments.—*King Radio Corp., Merriam, Kansas.*

CIRCLE 237 ON READER-SERVICE CARD

CONSTANT CURRENT SUPPLY

New ITT Model P617B transistorized, 4-channel power supply for klystrons, large magnetic systems or other systems requiring a highly regulated constant current provides the



following ranges: 1.1 to 1.3 amp at 16.5 to 33.8 watts; 2 to 6 amps at 16.2 to 216 watts; 6 to 9 amps at 65 to 292 watts; and 3 to 5 amps at 27 to 135 watts.—*Industrial Products Div., International Tel. & Tel. Corp., 15191 Bledsoe St., San Fernando, Calif.*

CIRCLE 238 ON READER-SERVICE CARD

MU-SHIELDED TRANSFORMER

Subminiature transistor transformers shielded in Mu-Metal cans provides 20 to 30 db reduction over

steel cans. ¾" square x 1⅛" high or ⅛" diameter x ⅛" high, they meet MIL-T-27A-4-R with 10,000 hr reliable life.—*Microtran Co., Inc., Valley Stream, N. Y.*

CIRCLE 239 ON READER-SERVICE CARD

TURN COUNT DIAL

New 1360 Series turn-counting Microdial logs turns for accurate reading and re-setting, provides brake for locking settings and is

available in combinations of red, gray and black colors inlaid in plastic.—*Borg Equipment Div., Amphenol-Borg Electronics Corp., 120 So. Main St., Janesville, Wisc.*

CIRCLE 240 ON READER-SERVICE CARD

Beryllium Compounds in Reactor Applications

Beryllia, the oxide of beryllium, has refractory and nuclear properties which make it interesting for use as a structural material for fuel elements, a reflector, or a moderator for a high-temperature nuclear reactor. In the Daniels Pile, beryllia was proposed for the moderator, fuel elements and portions of the reflector. Beryllia is also being used as a reflector in the Bulk Shielding Facility.

Although it has desirable nuclear properties, beryllia, like other ceramics, is brittle. It has better resistance to thermal shock than most other ceramic materials and a higher melting point than any metal except tungsten, molybdenum, tantalum, rhenium or osmium. It is a good electrical insulator at elevated temperatures.

Beryllia crystallizes in the hexagonal system with a zincite (ZnO) type of structure. It is prismatic with a definite 1010 cleavage. Beryllia is an ionic crystal consisting of a close-packed array of oxygen atoms with beryllium atoms in the interstices, also close packed.

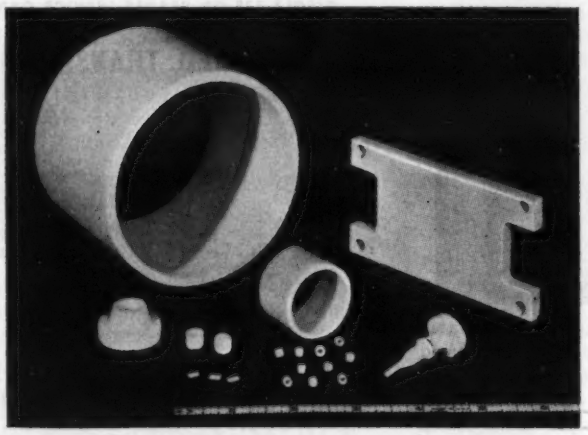


FIG. 1. TYPICAL BERYLLIA ceramic shapes in current production.

Beryllium and its compounds are toxic. Contact with the skin and inhalation of dust or fumes should be avoided. Permissible tolerance levels of beryllia dust in the atmosphere and precautions for handling beryllia in a plant or laboratory should be estimated by competent medical authority and observed rigorously.

Forming and Fabrication

Beryllia structures are fabricated by five methods: (1) hot pressing, (2) cold or dust pressing, (3) ramming (4) ceramic extrusion, and (5) slip casting. In each case, beryllia powder is the starting material, and, except for hot pressing, each of the forming operations is followed by a sintering treatment.

In hot pressing, a low-fired, high-purity powder is placed in a suitable die, and pressure is applied while the die is hot. Usually the die is made of graphite and is heated by resistance to 1600° to 2100°C. A pressure of 1000 to 2000 lb/sq in. is applied. Hot-pressed beryllia needs no sintering treat-

ment, since it is formed at high temperature.

Dust pressing, ramming, extrusion, and slip casting are conventional ceramic-forming methods. Generally, water and a small amount of bonding material are added to provide plasticity during forming and strength for the formed structure until sintering. Paraffin, gum, starch and various similar "binders" are satisfactory and, owing to their organic nature, completely burn out on sintering in an oxidizing atmosphere. Water is added in various quantities depending on the method of forming: in the case of slip casting, sufficient water to give a slurry that can be poured; a lesser amount, to provide the plasticity necessary for extrusion; or, for dust pressing or ramming, just enough to dampen the powder. When dust-pressed bodies are bonded with paraffin, no water is needed.

The tensile and compressive strengths of beryllia are dependent upon density, method of fabrication, and, of course, temperature. Denser bodies have higher strengths; ceramically extruded bodies are stronger than dust-pressed or slip-cast bodies of equal density. Like most ceramic materials, beryllia is several times stronger in compression than in tension. The effect of density on compressive strength is given in Fig. 1. (*From* 10- *page reprint of Chapter* 1.3 *"Beryllia," from The Reactor Handbook, Vol.* 3 *AECD-3647. Available on request from Coors Porcelain Co.,* 600 *Ninth St., Golden, Colorado. Also included is* 6-*page data sheet on Coor's Beryllia and Alumina Ceramics.*)

FOR THIS LITERATURE CIRCLE 241 ON READER-SERVICE CARD

SEMI CONDUCTOR FUTURE

CONTINUED from page 3

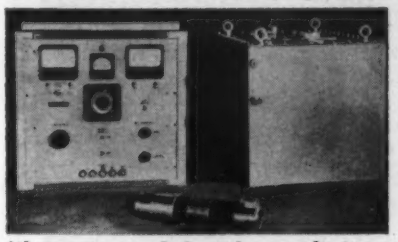
a compelling reason for solid-state circuits. Perhaps if we know how to protect such circuits well, this is an achievable virtue. We are getting there and can do it, but the yield is modest even on individual components.

"For what it's worth, my opinion is that desire is ahead of technology in solid-state circuits and that we'd better set about improving technology before talking about the wild blue yonder of molecular circuits' where each molecule is in the right place with an error well below one in a thousand. I am sure that publicity is ahead of technology. It's a somewhat easier field, and much less expensive to pursue.

"In my opinion, a manufacturer of micro-components has several years to enjoy a market for his products before he is superseded by solid state circuits, to say nothing of molecular circuits. Solid-state circuits are on their way and work on them is well advised. Five to ten years from now, I'd guess, they'll be in mass production. By then, they'll begin to take over, and when they do, we'll see a brand new kind of computer with redundant components like those in the human brain. In the meantime, I'll bet on the advisability of learning control, advancing technology, and using a lot of microcomponents, each tested for performance before assembly to avoid devastatingly low circuit yields and correspondingly high costs."

X-RADIATION GENERATOR

High intensity soft X-rays for environmental and other studies requiring 5 to 50 Kv at intensities up to 10^6 R/min are furnished by new Model 60-50 FWIP X-ray generator

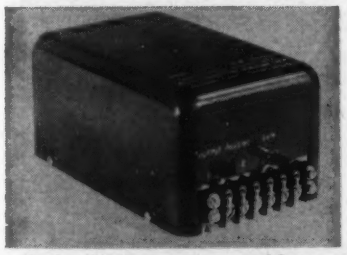


with water-cooled tube and transformer permitting continuous operation. X-ray tube features low absorption beryllium window and is available in a variety of target materials. —*Bracke-Seib X-ray Co., Inc.,* 16 *Pelham Bay Park West, Pelham Manor, N. Y.*

CIRCLE 242 ON READER-SERVICE CARD

AUDIO LINE AMPLIFIER

New transistorized compression audio line amplifier Type CA-5 for missile site communications, wind



tunnel facilities, etc., enables audio impulses to any of 50 microphones in parallel to be heard in all of 50 headsets connected in parallel to output.—*Flite-Tronics, Inc.,* 3314 *Burton Ave., Burbank, Calif.*

CIRCLE 243 ON READER-SERVICE CARD

CRYOGENIC & FUEL PUMPS

New utility pumps for cryogenic and petrochemical fluids in ground support systems using Skinner

Rotary Seals range in capacity to 1500 gpm at differential pressures to 500 psi, handling temperatures from —400° to 1200°F.—*Hydrodyne Corp.,* 7350 *Coldwater Canyon, No. Hollywood, Calif.*

CIRCLE 244 ON READER-SERVICE CARD

New Products—Continued

THERMAL VALVES

Bimetallic Klixon disc valve controlling gas or liquid flow through an orifice directly instead of via electrical contact and relay, provides either snap on-off or modulated control with lightest weight and highest reliability, for many missile, aircraft and ground support applications.—*Spencer Products Group, Metals & Controls Div., Texas Instruments Inc., Attleboro, Mass.*

CIRCLE 245 ON READER-SERVICE CARD

METALLIZED PAPER CAPACITORS

New Type P8292ZN plastic-cased metallized paper capacitors utilize a high-temperature solid impregnant to

eliminate all waxiness for improved appearance and ease in assembly. Technical data on complete line is available on request,—*Aerovox Corp., New Bedford, Mass.*

CIRCLE 246 ON READER-SERVICE CARD

FEEDBACK POTENTIOMETER

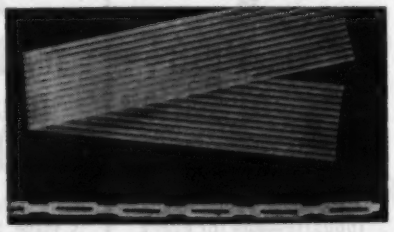
New wirewound Model 3-120 linear motion servo feedback potentiometer is designed for missile applications

to 500°F. Only ½" diameter, they may be installed inside the actuator shaft, are available in 1" to 5" strokes.—*Edcliff Instruments, 1711 So. Mountain Ave., Monrovia, Calif.*

CIRCLE 247 ON READER-SERVICE CARD

PRINTED CIRCUIT CABLES

New printed circuit cables using all Teflon TFE insulation, and with silver- or nickel-plated copper strip



conductors, can be made up to 3" wide and with insulation over conductors as thin as 0.002".—*W. L. Gore & Associates, Inc., 487 Papermill Rd., Newark, Del.*

CIRCLE 248 ON READER-SERVICE CARD

MAGNETIC SHIELD

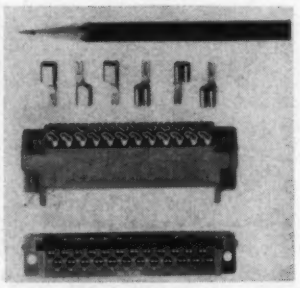
Netic Co-Netic magnetic shield for Hughes Type H-1010AP20 Tonotron Storage Tube assures maximum resolution regardless of proximity of oth-

er components. May be permanently potted because periodic annealing is not required.—*Magnetic Shield Division, Perfection Mica Co., 1322 N. Elston Ave., Chicago 22, Ill.*

CIRCLE 249 ON READER-SERVICE CARD

TWIN-PIN CONNECTOR

New Series 7009 Elco Varitwin-Pin printed circuit connector provides each contact with 4 coined mating

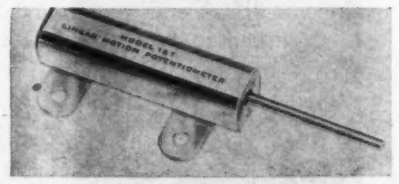


surfaces for high contact reliability and low resistance. Set in rugged glass-filled diallyl phthalate.—*Mr. I. L. Fien, Fien & Schwerin, Inc., 12 S. 12th At., Philadelphia 7, Pa.*

CIRCLE 250 ON READER-SERVICE CARD

QUIET LINEAR POT

Model 157 Align-O-Pot is a short stroke linear motion potentiometer with self-aligning shaft with low



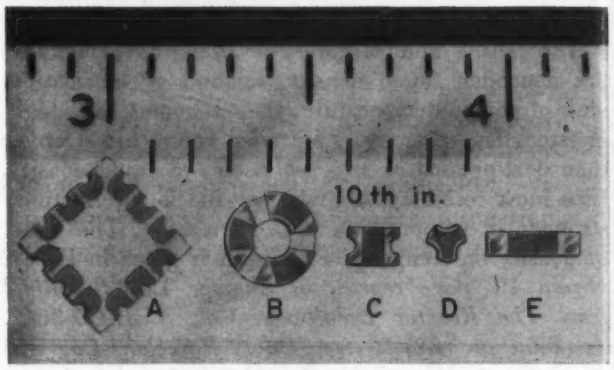
noise even under 40 G vibration. 1K to 20K ohms resistance, with travel ranges ⅛", 1" and 1⅜", operating temperatures —65° to 374°F.—*Bourns Inc., P.O. Box 2112, Riverside, Calif.*

CIRCLE 251 ON READER-SERVICE CARD

Custom-Built Micro Resistors

Design engineers attempting to squeeze more functions into less and less cubic space will be glad to learn of a new custom service offered by the Filmohm Resistor Corporation. Micro-miniature module resistors, shown in 2 x enlargement, are typical of custom designed resistor conformations which now enable system designers to incorporate resistors into the smallest of "odd" corners.

The new modular resistors can be supplied on substrates in most 3-dimensional configurations, including non-symmetrical forms. Physical size is limited only by the ability to handle the resistor. Single or multi-element resistors of pure metal films may be



TYPICAL MODULE resistors are shown in 2x enlargement. Applications are: (A) Wafer resistor with up to 4 resistors on single micromodule substrate; (B) 3-resistor assembly to fit within the annulus of a miniature header; (C) Module resistor for placing between, and soldering directly to, two header pins; micro-miniature module resistor with three resistances on one surface for mounting between 3 header pins; and (E) resistor on rectangular micro-substrate.

deposited on a single substrate, and substrate materials of mica, glass, quartz or ceramic may be used.

Despite the versatility of the new resistor forms, short prototype runs of the custom-built modules are not expensive, according to Filmohm. No costly dies or machine parts are needed with the advanced substrate fabrication and film deposition methods used. Glass substrates are said to be particularly amenable to low cost production and fast delivery requirements, even in small quantities and unusual shapes.

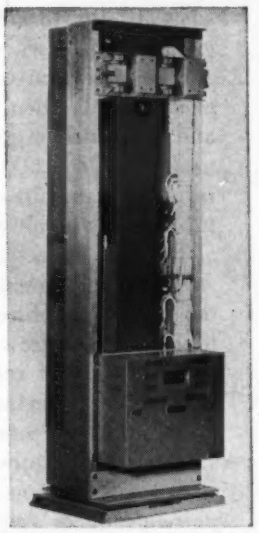
Filmohm Module resistive films, formed by the deposition of pure metal films on ultra-clean substrates, are first protected by a micro-thin coating of quartz, to which a final hard, impervious coating of silicone resin is added if required. Even without this final coat the modules are virtually unaffected by moisture and handling. (*From 2-page catalog data bulletin which also gives suggestions for customer's specification, Filmohm Corporation, 48 West 25th St., New York 10, N. Y.*)

FOR THIS LITERATURE CIRCLE 252 ON READER-SERVICE CARD

FOR MORE INFORMATION ON PRODUCTS REPORTED OR ADVERTISED, USE POSTAGE-FREE CARD BOUND IN THIS ISSUE

Vibration and Shock Control

Certain components and items of sensitive equipment installed in the Atlas, Titan, Polaris, Bomarc, Lacrosse and other important missiles are now being protected by all-metal Met-L-Flex mounting systems. Advanced space products will depend heavily upon the specialized engineering resources available at Robinson to achieve reliability through environmental control, while maintaining minimum limits in space and weight.



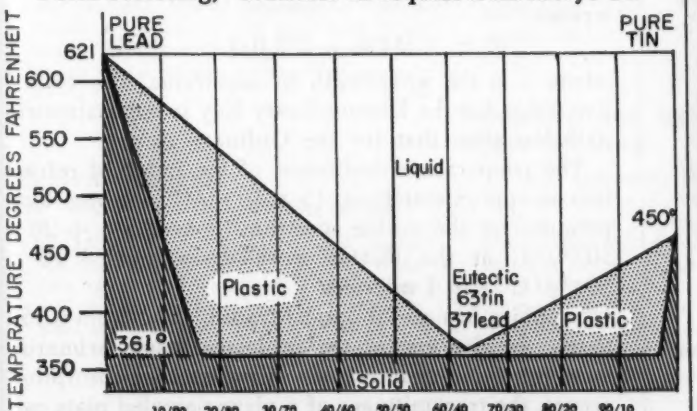
BULKHEAD and base mounting units cushion shocks. →

The Navy's new single-sideband communications equipment aboard surface ships and in the new nuclear submarines are cushioned by new low frequency shipboard mounting systems developed by the pioneer efforts of Robinson (See Figure). All-metal mounts have also been designed, tested and accepted to protect the latest communications and electronic equipment installed in tanks, jeeps, command cars, and other types of vehicles for the Army and Marines, and for the Air Force's supersonic fighter-bombers and interceptors, long-range strategic bombers, tankers, cargo and reconnaissance planes. Mounting systems W504-5 and W504-7 were the first all-metal mounts to pass the Signal Corps' Ballistic Shock Test (simulating gunfire impact), and the Package Test (simulating repeated road shock). (*From 4-page facilities brochure, Robinson Technical Products Inc., Teterboro, N. J.*)

FOR THIS LITERATURE CIRCLE 162 ON READER-SERVICE CARD

Solder Reference Data

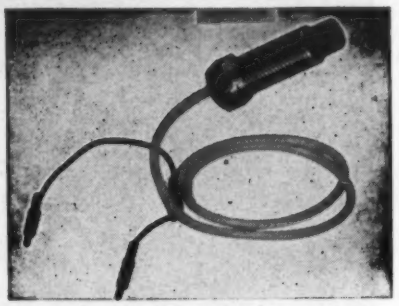
Six handy charts and tables providing convenient reference data relative to specific Pre-Form Solder alloys are contained in new 10-page "Guide to Pre-Form Soldering," available on request from Alloys Unlimited, Inc., 21-01 43rd Ave., Long Island City 1, N. Y. Additional information on the solderability of various metals, methods of flux application in automatic soldering and on flux removal in accordance with Government specifications is included.



FOR THIS LITERATURE CIRCLE 163 ON READER-SERVICE CARD

PROXIMITY SENSING HEAD

Improved head in ⅜" 24NF threaded stainless steel case fits all

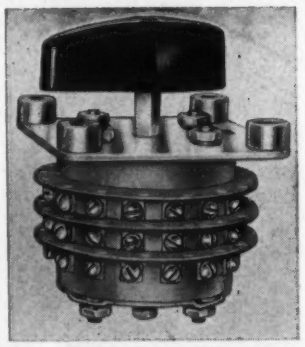


standard Bently distance detectors, widely used in vibration studies and in monitoring moving turbine blades, bearings, etc.—*Bently Scientific Co.*, 2811 *Seventh St., Berkeley* 10, *Calif.*

CIRCLE 164 ON READER-SERVICE CARD

ROTARY MULTIPOLE SWITCH

New ESCO type JK rotary 16-position switch provides 15 ON and 1 OFF positions for 3, 5, and 10 ganged

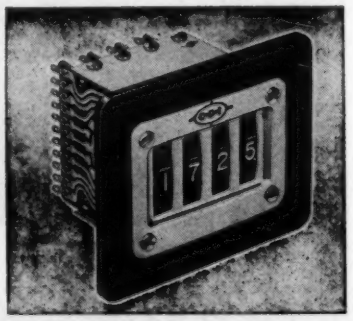


sections, rated at 5 amp, 125 v ac. Meets BuShips DRG 815-1853013 and MIL-S-21604.—*Electro Switch Corp., King. Ave., Weymouth* 88, *Mass.*

CIRCLE 165 ON READER-SERVICE CARD

THUMBWHEEL SWITCH MODULE

New modular digital switch, Series TSD, containing 1 to 6 thin thumbwheel switches in either 8, 10 or 12



positions with easy instant numerical readout is available with replaceable circuit wafers for easy maintainability or with fixed wafers. Quarter-inch Delrin thumbwheels are black or in color.—*Chicago Dynamic Industries, Inc.*, 1725 *Diversey Blvd., Chicago* 14, *Ill.*

CIRCLE 166 ON READER-SERVICE CARD

Some Physical Properties of Synthetic Sapphire[1]

The physical properties of synthetic sapphire (Al_2O_3) make it valuable for special applications where conventional materials are inadequate. Sapphire has high transmission in the ultraviolet, visible and infrared spectrum and windows can be made which are mechanically strong and wear-resistant. In optical systems the low dispersion of sapphire and its low susceptibility to abrasion make it valuable for outside elements of lenses subject to severe mechanical abuse. A loss of transmission of not more than 3 per cent is encountered when the material is heated to 440°C and transmission properties in the infrared region are useful up to 1,500°C. Sapphire is superior to other infrared transmitting materials which scratch or fracture readily or have high reflection losses.

The low dielectric loss, high resistivity, mechanical strength and freedom from outgassing have led to the use of sapphire for output windows of low- and high-power microwave tubes, and for insulators and support rods of internal tube structures. The ability of sapphire to make vacuum seals to metal, ceramics, glass, and even sapphire offers many interesting possibilities to the tube designer.

A small amount of chromium added to pure sapphire produces ruby. The paramagnetic resonance of the Cr^{+++} ion in the crystal lattice is used for microwave maser amplifier applications. Available data indicate a resonance bandwith of approximately 50 mc for very small amounts of chromium doping, increasing to about 570 mc with a higher doping of approximately 1 per cent chromium in aluminum sites. The chromium impurity in "pink" ruby is less than 0.1 per cent, in "standard" ruby between 0.1 per cent and 0.5 per cent and in "dark" ruby greater than 0.5 per cent.

Where special applications require accurate crystal orientation, a precision of 0.5° can be achieved by optical methods and 0.01° by X-ray techniques. Sapphire crystal structure is classified as a hexagonal system—rhombohedral class.

In the visible region of the spectrum the refractive index in Sapphire for the Ordinary Ray can be written

$$N_o = 1.74453 + 101.0/(\lambda - 1958)$$

where λ is the wavelength in angstroms. The refractive index for the Extraordinary Ray is approximately .008 less than that for the Ordinary Ray.

The temperature coefficient of the index of refraction is approximately $+13 \times 10^{-6}/°C$ at room temperature for the visible spectrum. It averages $+20 \times 10^{-6}/°C$ at the storter wavelengths and $+10 \times 10^{-6}/°C$ near 4 microns.

Sapphire has useful optical transmission from 0.15μ to 6μ. In the visible region losses result primarily from reflection at interfaces. If no internal absorption occurs, the transmittance of a plane-parrallel plate can be expressed as a function of the refractive index N.

$$T = 2N/(N^2 + 1)$$

where internal reflections are considered.

At wavelengths shorter than 0.3μ internal absorption

results in an additional decrease of transmission.

In the infrared region, transmission is maintained out to approximately 4 microns. At longer wavelengths internal absorption decreases transmission (Table I).

TABLE I. INFRARED TRANSMITTANCE OF SAPPHIRE

Wavelength Microns	Transmittance of 0.94 mm Plate
3.0	92%
5.35	84%
6.3	34%

The coefficient of absorption at $\lambda = 5.35$ microns is 1.9 cm.$^{-1}$ and at $\lambda = 6.3$ microns is 7.6 cm.$^{-1}$

[1]This article has been adapted from a 9-page technical paper by R. A. McFarlane entitled "A Summary of Available Data on the Physical Properties of Synthetic Sapphire", published by and available without charge from the *Sapphire Products Div., Adolf Meller Co., P.O. Box 702, Providence 1, R. I.*

Write direct to company.

Case Design in Rigidized Aluminum

Patterned rigidized aluminum is credited with minimizing weight and maximizing heat dissipation in a new Military combination transit and instrument case designed by MM Enclosures, Inc. to meet the special requirements and specifications of the GPL Division of General Precision, Inc. The new case is used to house test equipment for flight line maintenance of GPL doppler radar navigational systems.

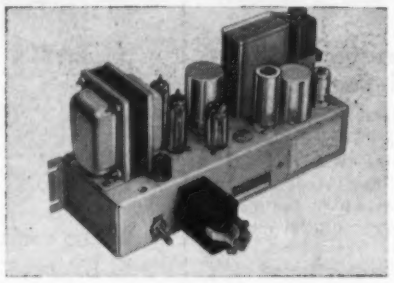
Because of the rigidizing effect of the dimpled pattern, the thickness of the aluminum sheet was reduced from 0.064" to 0.040", effecting a weight reduction of approximately 20%. Also, the patterned surface of the rigidized aluminum provides an estimated 12% to 15% greater heat-dissipating area, which acted as a "heat sink", eliminating the need for any internal blower or heat absorbing device for the test equipment.

The new case solution is typical of the service provided by MM Enclosures, Inc., 11 Bloomingdale Rd., Hicksville, L. I., N. Y. in designing military cases to meet all applicable Mil Specs and Customer requirements, in limited or production quantities in a wide range of sizes, shapes and metals.

FOR MORE INFORMATION CIRCLE 167 ON READER-SERVICE CARD

HI-STABILITY SERVO-AMP

New compact high-gain servo amplifier sensitive to a 3 μv change in input signal has a ± 2 μv stability,

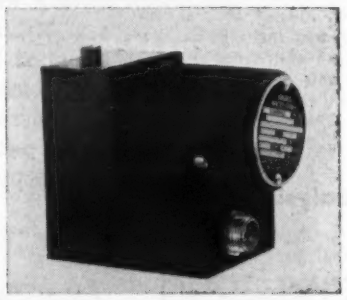


enabling self-balancing systems of laboratory accuracy to maintain performance ratings despite interference and variations in power supply. Servo motor with matching characteristics, is supplied.—*Thermo Electric Co., Inc., Saddle Brook, N. J.*

CIRCLE 168 ON READER-SERVICE CARD

MINI ROTARY ACTUATOR

New NYLC rotary actuator providing 35 lb-in breakaway torque is said

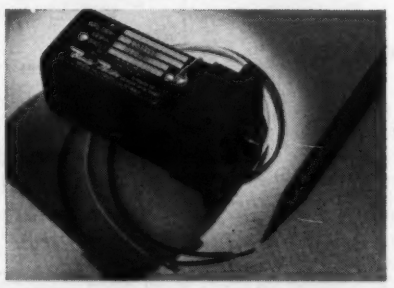


to be 50% smaller in size, weighs only 0.65 lb with radio noise filter. Bulletin F-9554-1 has technical details.—*Barber-Coleman Co., Aircraft Controls Div., Rockford, Ill.*

CIRCLE 169 ON READER-SERVICE CARD

ROTARY ACTUATOR

High-speed rotary drive actuator with internal slip clutch is designed to drive safe-arm mechanisms against external mechanical stops without

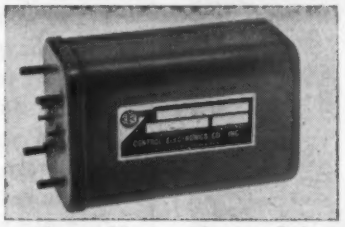


damage. Can be designed into any equipment requiring angular actuation requiring up to 1.0 lb-in torque. Drives 1.5 lb-in load 90° in 55 msec; weighs only 8.5 oz.—*Bendix-Pacific Div., Bendix Aviation Corp.*, 11600 *Sherman Way, No. Hollywood, Calif.*

CIRCLE 170 ON READER-SERVICE CARD

SQUARE WAVE FILTER

New LF-125 square wave filter is designed to maintain a constant insertion loss to within 0.1 db over an input signal range of 0-20 v rms; while

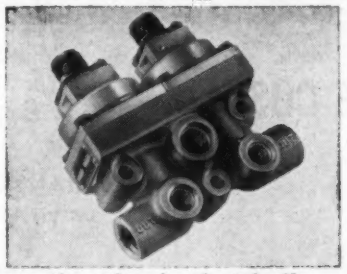


converting a 30 cps, 60 v peak-to-peak square wave into a sine wave output with less than 1% distortion. Input impedances of 50K and 100K ohms are available.—*Control Electronics Co., Inc., 10 Stepar Place, Huntington Station L. I., N. Y.*

CIRCLE 226 ON READER-SERVICE CARD

DUAL COIL VALVE

Designed for nose cone attitude control in outer space, Model MV-162

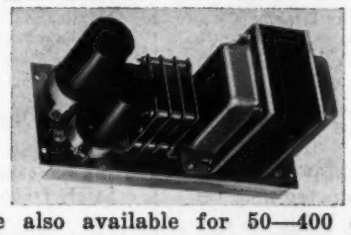


pneumatic valve is electrically actuated to provide 300 psig air to two reaction nozzles for pitch, yaw and roll control. Two 24 v dc coils control the 3-way, 3-position valve.—*Marotta Valve Corporation, P.O. Box 330, Boonton, N. J.*

CIRCLE 227 ON READER-SERVICE CARD

MODULAR DC SUPPLIES

Silicon rectifiers are provided in ten of Dressen-Barnes' Modular dc supplies with outputs from 28 v, 2 amp, to 500 v 300 ma. Nine of the ten

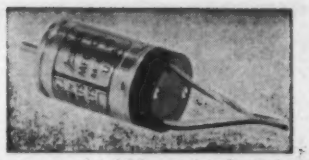


are also available for 50—400 cps 105-125 v input operation. The modules are designed for use individually or with D/B's multiple output rack mounting kits,—*Dressen-Barnes Corp., 250 No. Vinedo Ave., Pasadena, Calif.*

CIRCLE 228 ON READER-SERVICE CARD

SYNCHRO CONTROL TRANSFORMER

New Type 4227-01 400-cycle synchro control transformer with minimum error variations from —55°C to 125°C features input voltage, 11.8v.,



input current .030 amp, input watts 073 w, output voltage 22.5 v, phase shift 9.5°. Full characteristics on request.—*John Oster Manufacturing Co., Avionic Div., 1 Main St., Racine, Wisc.*

CIRCLE 229 ON READER-SERVICE CARD

SOLID STATE DELAY RELAY

New Economy series Solid-state Time Delay Relays in fixed or adjustable versions have nominal accuracies of ±1% and ±5% in the time

period of 0.5-110 seconds over the temperature range of —20°C to 85°C. Maintain timing accuracy even when voltage varies up to 30% of nominal value.—*Marstan Electronics Corporation, 204 Babylon Turnpike, Roosevelt, L. I., N. Y.*

CIRCLE 230 ON READER-SERVICE CARD

ASPIRIN SIZE SWITCH

New hermetically sealed precision switch filled with a dry inert gas has capacity of 3 amp, 28 v dc resistive,

SPDT contact, actuating force is 12 oz ± 8 oz, release force 1 oz min.—*Spencer Products Group, Texas Instruments Incorporated, 34 Forest St., Attleboro, Mass.*

CIRCLE 231 ON READER-SERVICE CARD

SEQUENTIAL DELAY RELAY

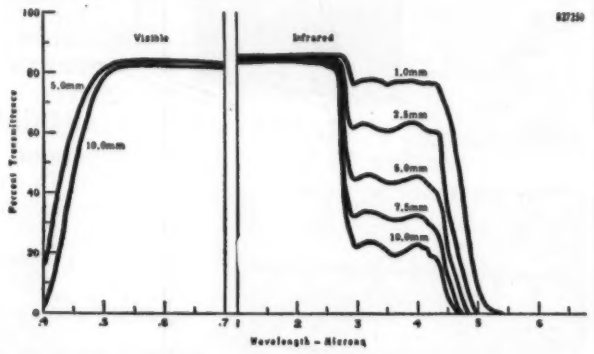
New sequential time delay relay Type 50-139-1 provides a series of 5 SPDT relay actions energized at one

second interval after actuation. Types 50-139-3 is similar, with 10-second delays to provide a total of 60 seconds total delay—*Electronic Dept., Hydro-Aire Co., 3000 Winona Ave., Burbank, Calif.*

CIRCLE 232 ON READER-SERVICE CARD

Glasses for Near-IR Refractive Systems

Three new glasses, initially designated as C-601, F-158 and A-2059 by the National Bureau of Standards, have been developed for refractive systems to be used in the near-infrared portion of the spectrum, by the Bausch & Lomb Optical Co., Rochester, N. Y. Known as Types 827250, 850324, and 915213 respectively, the new glasses may be classified in much the same manner as other optical glasses catalogued by that company. These are some of the products handled by the recently established Military Products Division, which specializes in Infrared Optical and electrical systems.



TRANSMISSION characteristics, Type 827250 impared transmitting glass.

The material can be supplied either as molded blanks or as slabs in Grades B and C. Reheating and molding of the material requires somewhat more skill than conventional glasses, but special assistance and data on fabrication techniques for the IR glasses is available from the supplier. Conventional optical surfacing techniques are employed, although the lower thermal shock resistance of IR glass requires extra precautions.

	827250	850324	915213
Optical Properties			
Nominal n_D	1.827	1.850	1.915
Nominal V	25.0	32.4	21.3
Nominal Transmittance	Fig. 1	Fig. 2	Fig. 3
Bubble Code*	2	4	1
Physical Properties			
Density (Sp. Gr.)	5.44	4.62	6.01
Top Annealing Temp.	750°F	1350°F	750°F
Safety Precautions	None	Contains Thorium	None

All glass is annealed in one of three ways:

1) *Precision Annealing*—so that it will have high optical homogeneity. Glass annealed in this manner will be uniform in refractive index throughout any given piece within 0.00002 and have a birefringence equal to fine annealing. An extra charge is made for precision annealing.

*Optical glass normally contains small bubbles, the content and size, varying with the different types of glass, from 0.002 mm to 0.5 mm in diameter. The bubble code classification has the following translation:

Bubble Code No.	1 2 3 4
Average No. Bubbles in 20cc.	1 2 4 40

2) *Fine Annealing*—So that the birefringence resulting from the permanent strain will produce a relative retardation or path difference of no more than 10 millimicrons for 1 cm of transmitted path of sodium light. No extra charge for this grade of annealing.

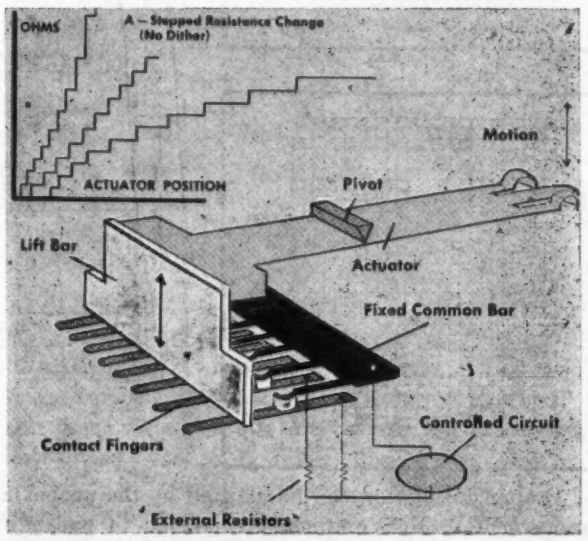
3) *Coarse Annealing*—so that the glass can be cut to size for future pressing without danger of chipping or shattering.

If optical components are to be produced directly from material furnished in slabs of plates, precision or fine annealing should be specified. If glass is to be molded to some desired shape, coarse annealing is sufficient. (*From 12-page Infrared Progress Report, N. 4., Military Products Div., Bausch & Lomb Optical Co., Rochester 2, N. Y. Previous B & L Infrared Progress Reports were briefed on page 224 in the Nov.-Dec. 1958 issue of MILITARY SYSTEMS DESIGN*).

FOR THIS LITERATURE CIRCLE 171 ON READER-SERVICE CARD

Electrical Position Transducer

New Regohm Transducer for translating micromovements of an actuating rod into precise control of up to one-quarter kilowatt of power is available in a variety of models. Control in a series of discrete resistance steps is accomplished in the simplest form of the transducer in which a series of contact fingers connected to external resistances are sequentially closed or opened (see Figure).



STEPPED CONTROL principle shown is basic control system used where stepless control is not required.

Development of the simple multi-contact transducer for stepless control is accomplished by the addition of a "dither" coil driven by a 60 cps source which averages the resistance values about any single actuator position, making the resistance changes smooth and stepless.

The Regohm Transducer is applicable to a wide range of military and industrial control devices because of its ability to directly control high power from low-level inputs without use of control amplifiers. (*From 4-page brochure, "Brushless Rheostat", Electric Regulator Corporation, Norwalk, Conn.*)

FOR THIS LITERATURE CIRCLE 172 ON READER-SERVICE CARD

MICROMINIATURE CONNECTOR

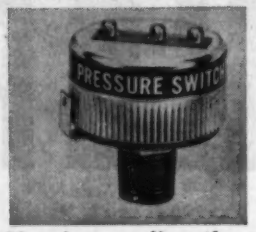
New "4A" series Snap-E-Lock microminiature closed entry socket connectors accommodate up to seven contacts within ½" diameter. Waterproof

with high breakdown voltage, lock-band locks automatically when connector is engaged.—*Viking Industries, Inc.*, 21343 *Roscoe Blvd., Canoga Park, Calif.*

CIRCLE 177 ON READER-SERVICE CARD

SUB-MIN PRESSURE SWITCH

New sub-miniature, 1-oz, adjustable pressure switch operates on pressures



up to 200 psi, exceeding the requirements of MIL-E-5272B in vibration, shock and acceleration. Pressure ranges and other information in bulletin AV2015.—*The Bristol Company, Waterbury* 20, *Conn.*

CIRCLE 178 ON READER-SERVICE CARD

VANE AXIAL BLOWER

New Type GR vane axial blower meeting Mil-Specs delivers 220 cfm air at 1.75" H_2O static pressure and 315 cfm at zero back pressure. Max

current at free air delivery is 1.8 amp, 115v, 60 cps with speed 8,000 rpm. Universal motor also permits use on dc. Blower is 4¾" dia x 6⅝" long.—*Globe Industries, Inc.*, 1784 *Stanley Ave., Dayton* 4, *Ohio.*

CIRCLE 179 ON READER-SERVICE CARD

AIR-BEARING PUMP

New pump designed for integral use with air-bearing gyro recirculates air for bearings without introducing

contamination. Hypoclycoid drive mechanism and welded diaphram bellows converts rotary to linear motion and provides sealed piston action in small 1½ lb package.—*Breeze Corporations, Inc.* 700 *Liberty Ave., Union, N. J.*

CIRCLE 180 ON READER-SERVICE CARD

MAGNETIC VISUAL CONTROL

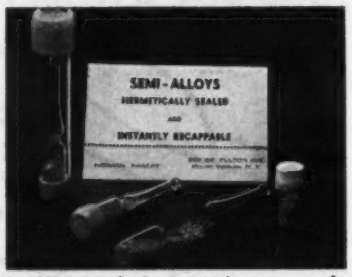
Visual control of business operations is now facilitated by Magne-trol magnetic personnel and production control boards, charts, and visual pre-

sentation. 12-page brochure and Magne-trol "Trial-Kit" offer, sent on request.—*Methods Research Corp.*, 105 *Willow Ave., Staten Island* 5, *N. Y.*

CIRCLE 181 ON READER-SERVICE CARD

HI-PURITY MICRO-SPHERES

Tiny spheres for transistor and tunnel diode fabrication in a variety of metals and alloys up to 99.9999% pure are supplied in recappable her-

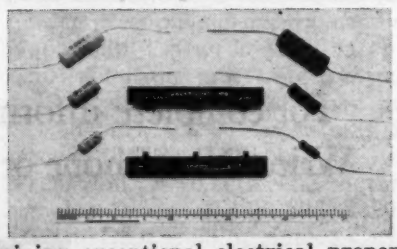


metically sealed containers enclosed with inert gas to provide indefinite shelf life. Aluminum, gold, silver and indium alloy production is being extended to virtually all metals. Fabricated to diameters of 0.001" and smaller, sphericity is maintained to ±0.0001" on most metals.—*Semi-Alloys, Inc.*, 550 *So. Fulton Ave., Mount Vernon, N. Y.*

CIRCLE 182 ON READER-SERVICE CARD

EPOXY MOULDING COMPOUNDS

New EMC plastic materials for advanced electronic designs in mineral and glass-filled types permit molding at soft flow, low pressure while main-



taining exceptional electrical properties and moisture resistance. Delay lines and R-F chokes illustrated are by courtesy Essex Electronics; resistors, courtesy of Clarostat Mfg. Co., Inc.—*American-Marietta Co., Seattle, Wash.*

CIRCLE 183 ON READER-SERVICE CARD

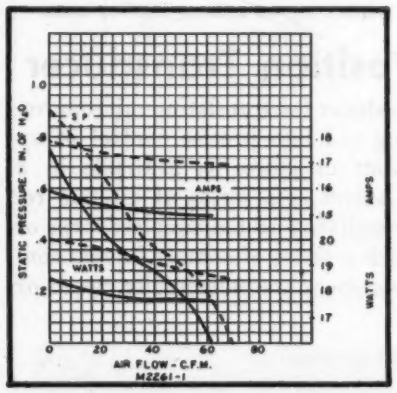
How to Select a Fan

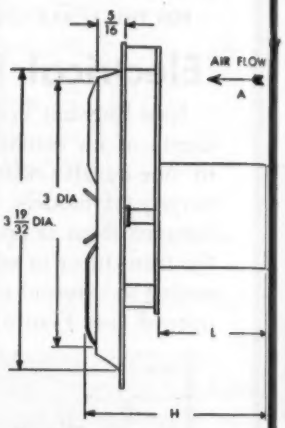
In order to select the proper fan for an air cooling application, the design engineer must consider many features. The actual cooling is accomplished by the weight flow of air (lbs. per min.) through the cooling circuit. The volume or weight flow of air can be determined for standard sea level conditions by use of the following formula:

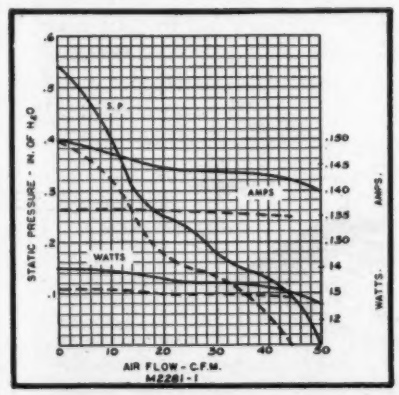
$$CFM = \frac{3160\ KW}{\Delta T}$$

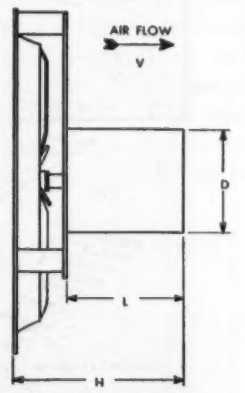
CFM = Cubic Feet per minute of air required.
ΔT = Temperature rise of cooling air in °F.
KW = Power in kilowatts dissipated inside enclosure.

This volume of air will satisfactorily cool the equipment if properly circulated through and around the hot components.









Proper circulation can be assured by the proper arrangement of the components involved in packaging the equipment. Hot spots can be eliminated by locating the most critical components in positions where the air flow would be the greatest. Proper positioning also can be helpful in reducing the static pressure involved through the air circuit, thus decreasing the size of the motor required for the fan assembly.

When both the volume flow of air required and the static pressure have been set, the selection of a proper fan can be made. Other features such as electical power available, space available, and noise limitations will also enter into the final decision.

Axial type fans are generally satisfactory for air movement where the back pressure involved does not exceed more than 0.25" wg. This figure basically applies to the 60 cps fan assemblies and not to the higher speed, 400 cps units. Where 400 cps power is avail-

able, higher speed fans can operate against higher back pressures. However, such features as noise limitation and size, speed and bearing life should be considered before final fan selection has been made.

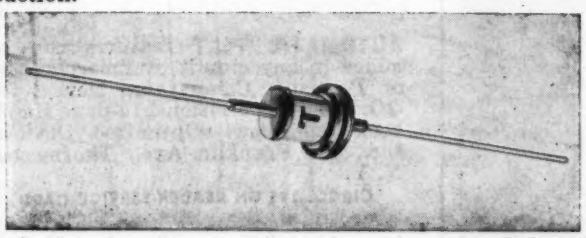
After a fan is picked for satisfactory air flow characteristics, other factors must be considered. First, will the fan fit into the space available in the equipment. If not, either a higher speed unit or two smaller fan assemblies operating in parallel, would be a possible solution. Secondly, the direction of air flow should be considered. You will note that on the performance graph, curves are shown for both directions of air flow. The solid curves are given for "V", air over motor. This means that the air goes through the propeller first and out over the motor. The dashed curves are given for "A", air away from motor. This means the air comes past the motor then out through the propeller. For example, an inlet fan mounted internally in a cabinet would generally be air flow "V". Conversely, an exhaust fan mounted internally in the equipment would be air flow "A".

(*From* 16-*page catalog "Axial Fans", Air-Marine Motors, Inc.,* 369 *Bayview Ave., Amityville, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 184 ON READER-SERVICE CARD

Radiation-proof Silicon-Carbide Diodes

First commercially available silicon-carbide rectifiers to withstand both high temperatures and high radiation levels are announced as being in pilot production by the Transistron Electronic Corp., Wakefield, Mass., with orders being accepted for prototype production.



Said to be able to withstand temperature of 500°C and to be up to 100 times less subject to radiation damage than silicon types, they may be used in ambient temperatures over 200°C, the present upper limit of silicon rectifiers. Typical reverse currents are less than 100 μa at 50 volts at 500°C. Actual size is shown in illustration.

Specifications of New Silicon-Carbide Rectifiers

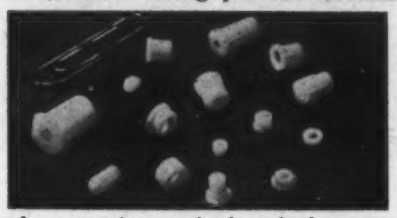
Type	Peak Inverse Voltage	Maximum Inverse Current Ib		Max Forward Voltage @ 100 ma	
		At 500°C	At 25°C	At 500°C	At 25°C
TCS10	100 v	500 μa	10 μa	4v	12v
TCS5	50 v	500 μa	10 μa	4v	8v

Exposure of the silicon carbide rectifiers to a neutron bombardment of 2 x 10^{16} nvt caused the forward voltage to change by only 5%. No significant inverse characteristic changes were observed. Such superior radiation resistant properties will make the new rectifiers useful in such devices as neutron counters and other applications where radiation flux levels are excessive for silicon or germanium devices.

FOR MORE INFORMATION CIRCLE 185 ON READER-SERVICE CARD

TEFLON CHASSIS BUSHINGS

New "Press-fit" teflon bushings for through-hole wiring provide mechan-



ical protection and electrical protection for insulated or uninsulated wiring passing through a metal chassis. —*Sealectro Corporation,* 610 *Fayette Ave., Mamaroneck, N. Y.*

CIRCLE 186 ON READER-SERVICE CARD

NYLON/DELRIN PARTS

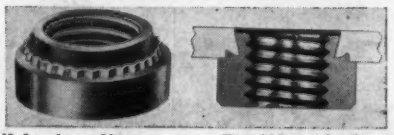
Parts available from molded Nylon and Delrin include stock mold and

special designs. Six-page catalog with additional sheets sent periodically is available.—*Nylomatic Corp., W. Trenton Ave., Morrisville, Pa.*

CIRCLE 187 ON READER-SERVICE CARD

SELF-CLINCHING FASTENER

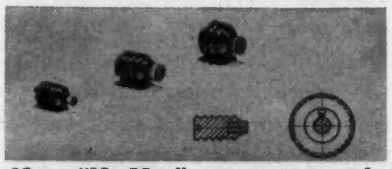
New self-clinching "Midget" fasteners can be squeezed into previously punched or drilled holes in sheet metal, using any standard pneumatic or



oil-hydraulic press. Positive lock in sheet metal gives high push-out and torque resistance but does not project on reverse side of sheet.—*Penn Engineering & Mfg. Corp., Doylestown, Pa.*

CIRCLE 188 ON READER-SERVICE CARD

NYLON-TIPPED SET SCREWS



New "No-Mar" set screws, when applied in a gear or hub and tightened to a basic shaft, protects the shaft from marks or mars and provides full face contact rather than 2-point as in conventional cup-point set screws. Nylon tip also acts as self-locking washer.—*PIC Design Corp.,* 477 *Atlantic Ave., East Rockaway, L. I., N. Y.*

CIRCLE 189 ON READER-SERVICE CARD

EMPLOYMENT OPPORTUNITIES

MSD new literature

INFRARED SYSTEMS design facilities and achievements are presented in new Military Products Group 10-page brochure.—Minneapolis-Honeywell Regulator Co., 2600 Ridgway Rd., Minneapolis 40, Minn.

CIRCLE 190 ON READER-SERVICE CARD

INFRARED INTERFERENCE control through Infratron interference filters is described in new 4-page Tech. Bulletin No. 6.—Infrared Industries, Inc., Waltham 54, Mass.

CIRCLE 191 ON READER-SERVICE CARD

DATA RECORDER MODERNIZATION saving space, calibration time, power and air-conditioning costs can be done by your own technicians. New 8-page bulletin 55A tells how.—Precision Instrument Co., 1011 Commercial St., San Carlos, Calif.

CIRCLE 192 ON READER-SERVICE CARD

SEALING OILS, waxes & greases for high vacuum equipment are described in Apiezon® bulletin No. 43.—James J. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.

CIRCLE 193 ON READER-SERVICE CARD

AUTOMATIC TEST features can be added to any circuit by incorporation of Precision Comparator Device for GO, NO—GO decisions. 14-page Handbook tells how.—Optimized Devices, Inc., 864 Franklin Ave., Thornwood, N. Y.

CIRCLE 194 ON READER-SERVICE CARD

GERMANIUM DIODES of 613 types are listed with characteristics in new 6-page bulletin 158C.—Ohmite Manufacturing Co., 3683 Howard St., Skokie, Ill.

CIRCLE 195 ON READER-SERVICE CARD

SILICON RECTIFIERS in all Columbus Semiconductors types and styles are listed with characteristics in new 6-page short-form catalog.—Columbus Electronics Corp., 1010 Saw Mill River Rd., Yonkers, N. Y.

CIRCLE 196 ON READER-SERVICE CARD

TRANSISTOR APPLICATION Guide booklet classified transistor types by performance graphs in major applications, includes list of pertinent data sheets containing circuit design information.—Philco Corporation, Lansdale Div., Lansdale, Pa.

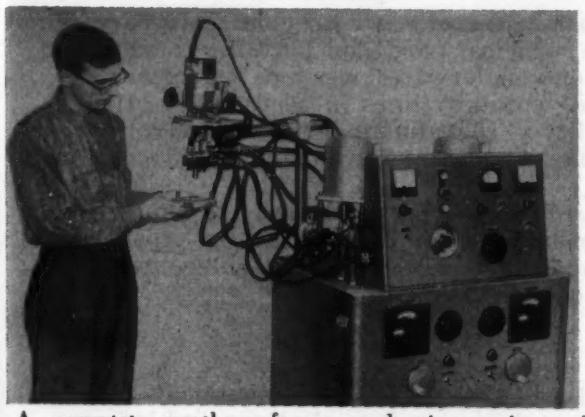
CIRCLE 197 ON READER-SERVICE CARD

SOLID-STATE TIMING module characteristics and circuits are described in new 16-page Eng. Bulletin 5906.—Tempo Instrument Incorporated, P. O. Box 338, Hicksville, N. Y.

CIRCLE 198 ON READER-SERVICE CARD

Small-Shot Urethane Foam Unit

Encapsulation of subminiature components in polyurethane foam is superior to solid epoxy encapsulation in many cases because, (1) the foam is from 20 to 30 times lighter, (2) foams do not split or stress components due to differences in coefficients of expansion between components and encapsulating material, (3) and because foams can be formulated over a wide range of densities and flexibilities to provide optimum support for any type of components and range of environmental conditions.



A complete urethane-foam production unit engineered for pumping, proportioning, mixing and dispensing two-component polyurethane foams using polyester, polyether or castor-oil bases is now available in the Martin Sweets Co. Miniature Model here illustrated. Its output is variable from zero to two pounds per minute of rigid, semi-rigid or flexible foams.

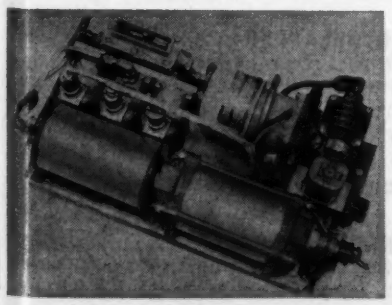
The unit is now in use in a number of research and foam development laboratories as well as meeting the rigorous demands of major production facilities operating around the clock. End products are utilizing the unusual characteristics of polyurethane foams for adhesion, flotation, packaging, thermal insulation, structural rigidity, shock absorption, sound deadening, encapsulation, cushioning, filtering and molding.

Engineers of the Martin Sweets Company, Inc., 114 So. First St., Louisville, Ky., welcome inquiries concerning specific processes.

FOR MORE INFORMATION CIRCLE 204 ON READER-SERVICE CARD

Dehydrator Unit

New combination Pressurization and Dehydrator Unit features automatic self-reactivation eliminating desiccant replacement. Meets MIL E-5400 and MIL M-7969A specs, and can be used on a variety of specific airborne, shipboard, undersea, and ground support equipment. — Great Lakes Mfg. Corp., 4223 Monticello Blvd., Cleveland 21, Ohio.



CIRCLE 234 ON READER-SERVICE CARD

GERMANIUM TRANSISTORS in 412 types in stock or production are listed in 4-page availability catalog.—Electronic Transistors Corp., 9226 Hudson Blvd., No. Bergen, N. J.

CIRCLE 199 ON READER-SERVICE CARD

INDUSTRIAL TRANSISTORS and Zener Diodes with certified reliability of military approved units are listed in 12-page catalog.—Motorola Semiconductor Products Div., 5005 E. McDowell Rd., Phoenix, Ariz.

CIRCLE 200 ON READER-SERVICE CARD

TRANSISTOR ADAPTORS to permit three-terminal measurement of transistor parameters with the Type B-601 RF Bridge are described in new two-page bulletin WK-Q-601.—Wayne Kerr Corp., 1633 Race St.. Philadelphia 3, Pa.

CIRCLE 201 ON READER-SERVICE CARD

THERMISTOR and Varistor Kits for design and experimental applications are described in a 2-page catalog sheet SF-102.—Victory Engineering Corp., 534 Springfield Rd., Union, N.J.

CIRCLE 202 ON READER-SERVICE CARD

CONTRACT MANUFACTURING Services available on emergency and immediate production of long- and short-run electrical, electronic and mechanical operations by experienced employees are described in 8-page facilities brochure.—Paraplegics Mfg. Co., 10068 Franklin Ave., Franklin Park, Ill.

CIRCLE 203 ON READER-SERVICE CARD

FERRITE CIRCULATORS and isolators in more than 60 models are listed in new 4-page catalog.—Sylvania Electric Products Inc., Central Advertising Dist. Dept., 1100 Main St., Buffalo, N. Y.

CIRCLE 205 ON READER-SERVICE CARD

ULTRASENSITIVE Receiving Systems facilities brochure described capabilities for research and development in communications, telemetry, and navigation.—L E L, Inc., 380 Oak St., Copiague, L. I., N. Y.

CIRCLE 206 ON READER-SERVICE CARD

MICROWAVE COMPONENTS, coaxial and waveguide attenuators and terminations are described in new 16-page catalog.—Radar Design Corp., P. O. Box 38, Syracuse 11, N. Y.

CIRCLE 207 ON READER-SERVICE CARD

STANDING WAVE AMPLIFIER, Type PRD 277B with extremely low noise level is described in new 2-page catalog data sheet.—Polytechnic Research & Develpoment Co., Inc., 202 Tillary St., Brooklyn 1, N. Y.

CIRCLE 208 ON READER-SERVICE CARD

HIGH DENSITY DELAY LINES, how they are used, what they will do, is explained in 18 page booklet.—Valor Instruments, Inc., 13214 Crenshaw Blvd., Gardena, Calif.

CIRCLE 209 ON READER-SERVICE CARD

QUARTZ DELAY LINES in eight types are described in new set of data sheets.—Computer Products Div., Laboratory for Electronics, Inc., 1079 Commonwealth Ave., Boston, Mass.

CIRCLE 210 ON READER-SERVICE CARD

CERAMIC TRANSDUCER elements US100, US500 and US600 are described in series of 1-page technical data sheets.—U. S. Sonics Corp., 625 McGrath Highway, Somerville 45, Mass.

CIRCLE 211 ON READER-SERVICE CARD

CENTRIFUGE ACCELERATION Test Machines, Series 10 and 20, for 100-G testing of missile components or some full-scale missiles, are described in new 8-page bulletin.—The Rucker Co., 4700 San Pablo Ave., Oakland, Calif.

CIRCLE 212 ON READER-SERVICE CARD

AIRCRAFT INSTRUMENTS manual giving installation data on meters, resistance and thermocouple thermometers, and ILS indciators has 48-pages.—D a y s t r o m, Incorporated, Weston Inst., Div., 614 Frelinghuysen Ave., Newark 12, N. J.

CIRCLE 213 ON READER-SERVICE CARD

WAVEFORM SYNTHESIZER Type 200, for Computer Programming, PCM-PTM, Servo Design & Test, Spectrum Simulation, Radar Pulse Coding, and other research aplications is described in new 4-page bulletin.—Exact Electronics, Inc., P. O. Box 552, Portland 7, Ore.

CIRCLE 214 ON READER-SERVICE CARD

NEW LITERATURE—cont.

MAGNETIC TAPE RECORDER for mobile and airborne applications is described in Bulletin 1607.—Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasedena, Calif.

CIRCLE 215 ON READER-SERVICE CARD

PRECISION RATE TABLES and other test equipment for Inertial Guidance components and systems are illustrated with specifications in new 24-page brochure, No. 153.—Sterling Precision Corporation, Instrument Div., 17 Matinecock Ave., Port Washington, L. I., N. Y.

CIRCLE 216 ON READER-SERVICE CARD

ACCELEROMETERS, Types 302 and 303 general purpose, and Types 606 and 607 subminiature, also high-temperature models, are described in 2-page catalog sheets.—Columbia Research Laboratories, MacDade Blvd. and Bullens Lane, Woodlyn, Pa.

CIRCLE 217 ON READER-SERVICE CARD

AIRBORNE PRESSURE transducers, Teleflight Model 181, with removable pressure cavities are technically described in new 2-page catalog sheet and price list P-59181.—Taber Inst. Corp., 107 Goundry St., No. Tonawanda, N. Y.

CIRCLE 218 ON READER-SERVICE CARD

LEADSCREW-Actuated Pot characteristics are illustrated and detailed in new 4-page summary "Trimpot" Brochure No. 5.—Bourns, Inc., 6135 Magnolia Ave., Riverside, Calif.

CIRCLE 219 ON READER-SERVICE CARD

SWEPT AUDIO MEASUREMENTS, techniques of using LP-1 Panoramic Sonic Spectrum Analyzer are described in 8-page Vol. 1 No. 5 issue of "The Panoramic Analyzer," Panoramic Radio Products, Inc., 514 So. Fulton Ave., Mount Vernon, N. Y.

CIRCLE 220 ON READER-SERVICE CARD

MULTICONDUCTOR CONNECTORS for Rack and panel mounting providing for from 50 to 156 contact inserts meeting Mil-specs are described in 2-page catalog sheet DTD2.—H. H. Buggie Div., Burndy Corp., P. O. Box 817, Toledo 1, Ohio.

CIRCLE 221 ON READER-SERVICE CARD

POTENTIOMETER Specifications of 37 single- and multi-turn precision potentiometers are listed in new 24" x 30" wall chart.—Spectrol Electronics Corp., 1710 So. Del Mar Ave., San Gabriel, Calif.

CIRCLE 222 ON READER-SERVICE CARD

CAPACITOR of commercial type using MYLAR dielectric encapsulated in solid epoxy is described in 2-page data sheet.—Good-All Electric Mfg. Co., 112 W 1st St., Ogallala, Nebr.

CIRCLE 223 ON READER-SERVICE CARD

WIRE MESH heating element properties of exceptional reliability and formability are dsecribed in new 16-page catalog.—Electrofilm, Inc., 7116 Laurel Canyon Blvd., North Hollywood, Calif.

CIRCLE 224 ON READER-SERVICE CARD

"PRINTED CIRCUITS, Value Analysis of," is title of new 15-page booklet by Arthur C. Ansley on design factors in printed circuitry.—Arthur Ansley Mfg., Co., New Hope, Pa.

CIRCLE 225 ON READER-SERVICE CARD

KNOBS meeting MIL-Specs are listed in new 2-page KMS Series Catalog bulletin No. 59-3B—National Radio Co., Inc., 37 Washington St., Melrose 76, Mass.

CIRCLE 253 ON READER-SERVICE CARD

MULTI-FLAPPER Check Valves for high-performance jet aircraft are described in new 4-page brochure.—Bobrick Aero Missile Products, Bobrick Mfg. Corp., 1839 Blake Ave., Los Angeles 39, Calif.

CIRCLE 254 ON READER-SERVICE CARD

VARIABLE CAPACITORS in standard tuning and trimming types are listed with complete electrical and mechanical specs in new 16-page catalog.—Hammarlund Mfg. Co., Inc., 460 West 34th St., New York 1, N. Y.

CIRCLE 255 ON READER-SERVICE CARD

MSD advertisers' index

This index is published as a service. Every care is taken to make it accurate, but MSD assumes no responsibility for errors or omissions.

CIRCLE 92 ON READER-SERVICE CARD →

MSD events

August 23-26—Western Electronic Sh and Convention, Sponsored by Los Angel and San Francisco IRE and WCEMA, A bassador and Memorial Sports Arena, L Angeles. Write Don Larson, WESCO Exhibits, 1435 La Cienega Blvd., Los Angele Calif.

September 14-15—4th Annual Joint Mi tary Industrial Electronic Test Equip. Sy posium, sponsored by Dir. of Research Eng neering, Dept. of Defense; Army Sign Corps; and Armour Research Foundation Ill. Inst. of Tech.

September 19-22—National Symposium o Space Electronics & Telemetry, sponsored b PGSET-IRE, Shoreham Hotel, Washingto D. C. Write Mr. Leon King, Exhibit Chm Jansky & Bailey, 1339 Wisconsin Ave., N. W Washington, D. C.

September 26-30—15th Annual Meetin Instruments Society of America, Colise New York City, N. Y., Write ISE, 313 Sixt Ave., Pittsburgh 22, Pa.

October 17-19—Symposium in Adaptiv Control Systems, Garden City Hotel, Ga den City, L. I., N. Y., Write Harold Le stein, Ch. Prog. Committee, W. L. Ma Corp., 460 W. 34th St., New York 1, N. Y

October 27-29—Aircraft Electrical Soc 1960 Industry Display, Pan-Pacific Aud torium, Los Angeles, Calif. Write McFad —Charlesworth Co., Inc., 9171 Sunset B Los Angeles 46, Calif.

November 14-16—12th Mid-American E tronics Conference, Hotel Muehleb Kansas City, Mo. Theme: "The Semicon tor 60's". Write L. R. Crissmon, Ch T.W.A., 10 Richards Rd., Kansas City,